A Geological Reconnaissance of Parts of Lee, Wise, Scott and Washington Counties, Virginia. By John J. Stevenson, Professor of Geology in the University of the City of New York. (With six wood cuts and a colored map.)

(*Read before the American Philosophical Society, January* 21, 1881.)

In a former memoir,* the writer described a small part of Lee and Wise counties, and gave some casual observations respecting a part of Scott county. Examination of a larger area has shown that two serious errors, due to too ready acceptance of information respecting localities not visited, occur in that memoir, and has led also to a change in opinion respecting the structure of Stone mountain.

The counties examined occupy the extreme south-west corner of Virginia; Lee being in the angle between Kentucky and Tennessee, with Wise adjoining it along the Kentucky line, while Scott and Washington lie next along the Tennessee border.

The surface is broken by rudely parallel mountain ranges, separated by narrow valleys. The distance along the shortest line from the city of Bristol to the Kentucky border is barely fifty miles, yet in following that line one must cross Walker, Brushy and Clinch mountains; Moccasin, Copper and Buckner's ridges, Powell mountain, Wallen's and Poor Valley ridges, Stone and Black mountains. Several of these ridges are single, and have abrupt slopes, while others are compound, and their slopes afford grades not too difficult for wagons.

The area between the Great Valley of Virginia and Moccasin ridge is drained by the Holston river; that between Moccasin ridge and Powell mountain, by Clinch river; and that beyond Powell mountain to the Kentucky line, by Powell river. The Clinch and Holston unite to form the Tennessee river, and Powell river enters the former at not far from Knoxville. Of these rivers, the Powell rises within the area examined; the others have their sources far beyond toward the north-east.

A narrow strip of this region along the Kentucky border has been examined by Mr. P. N. Moore, of the Kentucky Geological Survey, and a summary account of his observations is given in the reports of that Survey, Vol. IV. Prof. Lesley's work, as described in his memoir,† is slightly overlapped by the writer's examination. The whole region was examined during the survey under Prof. W. B. Rogers. One is compelled to regret

* Read before this Society, August 20, 1880.
† Proceedings of this Society, 1872.

that the reports of that survey are so rare; since the map prepared by Prof. Rogers and published in "The Resources of Virginia," shows that the structure was admirably worked out. The faults are clearly shown on that map, and the distinction between the limestones of the Lower Carboniferous and the Lower Silurian was determined accurately, though at that time there was little aside from physical characters to depend on for identification. When it is remembered that the region was even more thinly settled forty years ago than it is now, one may not refrain from acknowledging the skill and patience with which the structure was worked out at that early day.

To obtain the material given in this memoir, one section was followed from Black mountain almost directly to Bristol; a second from Pennington's gap in Stone mountain to the Tennessee line by way of Estillville and Moccasin gap through Clinch mountains; shorter sections were followed across Moccasin and Copper ridges; while several of the faults were followed for from ten to twenty miles. Necessarily, many interesting details were neglected, and some points of importance were left undecided, as the object of the reconnaissance was purely economic.

No map worthy of the name exists, and that accompanying this memoir is based on the old State map, made in 1825. Some gross topographical errors have been corrected partially; others remain, which interfere seriously with a proper presentation of the geology; but to correct these would involve a complete reconstruction of the whole.

I. General Structure of the Area.

The structure is monoclinal, and the prevailing dip is toward the southeast. The one exception is in the area between Black mountain and the summit of Powell mountain, where, as will be shown, a cracked anticlinal exists. In passing from Black mountain to the Valley of Virginia at Bristol, one crosses

1. *The fault of Poor Valley ridge.*
2. *The Wallen valley fault.*
3. *The Pattonsville fault.*
4. *The Hunter valley fault, or Clinch river uplift of Lesley.*
5. *The fault of Copper creek.*
6. *The fault of the North Fork of Holston.*
7. *The fault of Walker mountain.*

Black mountain is a rude mass, which owes its origin solely to erosion. It is the dividing ridge between the waters of the Cumberland and those of Powell and Clinch rivers. Its course is irregular but bears westward and southward until, at a little way west from Pennington's gap in Stone mountain, it unites with the latter ridge. The only rocks exposed in this mountain are those of the Coal Measures, and their dip is northward, or north north-west. Toward Stone mountain, the dip suddenly increases until in that ridge it becomes almost, and at some places, wholly vertical.

Stone mountain is a bold narrow ridge with a N. 67° E. course, which

begins not far beyond the Little Stone gap and continues thence into Tennessee. It was examined from Little Stone gap to nearly three miles beyond Pennington's gap, a distance of nearly thirty miles, in which it has but two water gaps, those of Powell river and its North Fork, or, as they are commonly known, Big Stone and Pennington's gaps. A wind gap, the Little Stone, affords passage for the turnpike leading from Jonesville to Gladesville.

In his former memoir, the writer regarded Stone mountain as a fault, but he is now convinced from the conditions observed at Pennington's gap, that the mountain is but the side of an exceedingly abrupt fold, as will be explained in another paragraph.

In the Poor Valley, which follows the southerly foot of Stone mountain, the Devonian shales are shown underlying the Lower Carboniferous. At the head of the valley, the Lower Carboniferous is well shown in the divide between the South Fork of Powell river and the waters of Stony creek, where it is in direct contact with the Lower Carboniferous of Stone mountain. In the divide, it dips gently toward the south-east, while in Stone mountain the dip is almost vertical, the incline being toward the north-west or north north-west. The dips in the mountain become sharper toward the west, being 70 degrees in Big Stone gap, and 90 degrees in Pennington's gap. The rocks shown in the mountain gaps are the Lower Carboniferous, the Quinnimont group and the lower beds of the Coal Measures.

The fault of Poor Valley ridge must be described before the structure of Stone mountain can be fully explained. This fault is very nearly parallel to Stone mountain, though the increasing strength of the thrust, by turning the rocks directly on edge, has diminished the interval materially in the vicinity of Pennington's gap. The distance between the two ridges varies from a mile to a mile and a half. At its eastern extremity, the fault begins in a gentle anticlinal nearly opposite Little Stone gap. A crack develops in this anticlinal near the gap, by which the South Fork of Powell river crosses it, and increases rapidly in importance westward. The Devonian shales cross the anticlinal at its origin, while in the divide at the head of the valley, the Lower Carboniferous and part also of the Quinnimont group pass over it so as to be continuous with the rocks of Stone mountain. But the anticlinal soon becomes bold, and the fault develops, so that the ridge is divided below the mouth of South Fork of Powell into Poor Valley ridge and Wallen's ridge. There the extent of the fault is shown, for the Clinton is in direct contact with the middle shales of the Knox group. Poor Valley ridge continues westward to beyond the Tennessee line, and varies much in height and width. It is composed chiefly of Clinton rocks, while the Lower Helderberg, Oriskany and Hamilton occur in the narrow valley between it and Stone mountain.

The writer has stated in another paper that Stone mountain is a fault, and that it is the continuation of the *Clinch river uplift* described by Prof. Lesley. Mr. Moore, in the report of his reconnaissance along the border

of Kentucky and Virginia, maintains that Stone mountain is not a fault, but that it is a sharp fold and a typical example of the Cumberland mountain structure. The exposures beyond Little Stone gap and at Pennington's gap show this to be true. It is precisely like the structure of Brush mountain, Kentucky, of which an illustration is given in a long cross-section accompanying another of Mr. Moore's reports. At Pennington's gap the succession of Upper Silurian, Devonian and Lower Carboniferous is clear, and all the groups are conformable. Figures 1, 2 and 3 exhibit the structure of the whole fold; No. 1 being a cross section from the northerly slope of Stone mountain to Powell mountain; No. 2, a similar section through Big Stone gap, and No. 3, the section from Pennington's gap to Wallen's ridge.

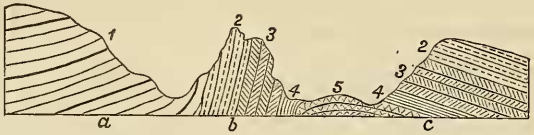

FIG 1.—Section from Stone mountain at Little Stone gap to Powell mountain. *a*, Slope of Black mountain; *b*, Stone mountain; *c*, Powell mountain; 1, Coal Measures; 2, Quinnimont group; 3, Lower Carboniferous; 4, Devonian; 5, Upper Silurian; 6, Lower Silurian.

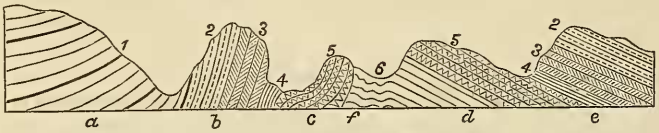

FIG. 2.—Section from Stone mountain at Big Stone gap to Powell mountain. *a*, Slope of Black mountain; *b*, Stone mountain; *c*, Poor Valley ridge; *d*, Wallen's ridge; *e*, Powell mountain; *f*, fault of Poor Valley ridge. Numbers as in preceding figure.

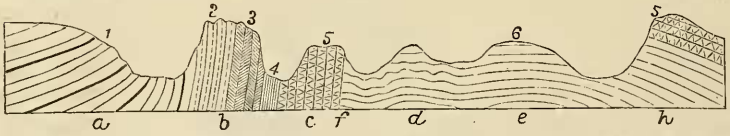

FIG. 3.—Section from Stone mountain at Pennington's gap to Wallen's ridge. *a*, Slope of Black mountain; *b*, Stone mountain; *c*, Poor Valley ridge; *d*, Chestnut ridge; *e*, Elk Knob; *h*, Wallen's ridge; *f*, fault of Poor Valley ridge. Numbers as in preceding figures.

The change of structure beyond the fault of Poor Valley ridge will be explained in its own place.

Wallen's ridge includes the eastern extremity of Poor Valley ridge, and the two ridges become separate only beyond the mouth of South Fork of Powell river. Lower Silurian rocks are shown on its northerly side, Medina sandstone forms the crest, while Lower Helderberg and Oriskany are shown on the southerly slope. The structure, where the ridge first separates itself from Poor Valley ridge, is shown in Fig. 2, which represents the cross-section from Poor Valley ridge fault across Turkey Cove,

and the mountain to Powell mountain. There the ridge is narrow ; but at some miles further west the conditions are as in Fig. 3, which shows the section from the Poor Valley fault on North Fork of Powell to the Wallen Valley fault near Stickleyville. Here instead of the single ridge seen at the Turkey Cove there are three ridges, known as Chestnut ridge, Elk Knob and Wallen's ridge. The folds in Chestnut ridge are exceedingly complex, and are well shown in the gap by which the North Fork of Powell river passes through it. The beds are folded without crushing, though some of the angles are as sharp and close as the bent elbow. But in Elk Knob the strata are practically horizontal until near the southerly slope where the dip becomes nearly 15 degrees. The rate increases toward Wallen's ridge as well as in the ridge, until, along the summit line, the Medina dips at nearly 40 degrees. The Upper Silurian rocks are reached on the southerly slope of the ridge.

The relations of Wallen's ridge to Powell mountain are somewhat complicated by the Wallen Valley fault, which begins at the head of Wallen's valley. As far as could be ascertained, no traces of that fault exist further east. That part of Powell mountain which lies east from Slemp's gap, through which the North Fork of Clinch flows, has a very different structure from that of the part lying west from that gap. The eastern division is but a continuation of Wallen's ridge, the separation being due solely to erosion ; for, on the bold bluff which Powell mountain presents to the valleys of the South Fork of Powell river and the North Fork of Clinch river, the section is but a continuation of that shown on the slope of Wallen ridge ; and the Lower Helderberg, Oriskany, Hamilton, Lower Carboniferous and Quinnimont group appear in regular succession, while the Quinnimont group covers the southerly slope of the mountain to where it is cut off by the Hunter Valley fault. The conditions observed on this side of Powell mountain will be described in connection with that fault.

The Wallen Valley fault begins at the head of that valley, and continues into Tennessee. It passes along the southerly side of Wallen's ridge, and is crossed by the Jonesville and Estillville road at, say, nearly half a mile from Wallen's creek. On its northerly side are the Lower Helderberg rocks, ill-exposed where examined, dipping almost south-east at 45 degrees, while the limestones of Formation III are shown on the southerly side dipping in the same direction at 30 degrees. The upper part of No. II is shown near the fault, but only a small part of that group is brought up where the examinations were made. It is not wholly certain that this fault begins within Wallen's valley, but no traces of it were seen on the other side of the mountain, where, however, the forest is dense, and exposures are few and not satisfactory. It is certainly absent from the valley of North Fork of Clinch at three miles further up. This fault is important economically, for, in great measure owing to its sudden development, Powell mountain west from Slemp's gap has been so far elevated that the Devonian, Lower Carboniferous and Quinnimont group, still present on the other division of the mountain, have been wholly removed by erosion.

Powell mountain west from Slemp's gap is but a repetition of Wallen's ridge as shown on the opposite side of Wallen valley. The limestones and shales of Formation III are exposed on its northerly side, Medina sandstone follows its crest, while the Lower Helderberg, Oriskany and a fragment of the Hamilton are shown on its southerly side. These rocks are suddenly cut off by the

Pattonsville fault, which is marked by a low ridge at, say, two-thirds of a mile from the crest of Powell mountain. No evidence of its presence was found beyond the railroad line, and, in all probability, it originates very near that line. The structure between the Wallen's valley fault and the Hunter Valley fault (Clinch uplift) is shown in Fig. 4. This fault

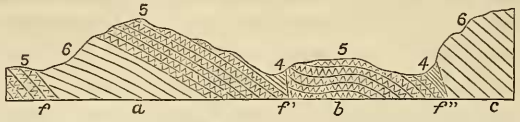

FIG. 4.—Cross-section through Powell mountain from the Wallen Valley fault to the Hunter Valley fault in Buckner's ridge. *a*, Powell mountain *b*, Pattonsville ridge; *c*, Buckner's ridge; *f*, Wallen's Valley fault; *f'*, Pattonsville fault; *f''*, Hunter Valley fault or Clinch uplift. Numbers as in Fig. 1.

brings up the Lower Helderberg rocks against the Hamilton shales; the former describe a shallow synclinal and low anticlinal, so that, before reaching the North Fork of Clinch river, the Hamilton shales are again exposed, dipping very sharply toward the south-east. The details of this fault cannot be expressed on the map, owing to the narrowness of the area affected by it. It is evidently parallel with the Wallen Valley fault, and it is responsible for the absence of the Lower Carboniferous rocks from the valley at the southerly foot of Powell mountain. This fault, according to Prof. Safford's map, does not exist in Tennessee.

The Hunter Valley fault is the same with the *Clinch river uplift,* which is so fully described by Prof. Lesley in his memoir on the geology of Wise and Tazewell counties.* As it lies at a considerable distance from Clinch river within the area under consideration, it is best to apply to it a local name. Its direction, as laid down on the map, does some violence to the truth, but the writer has preferred to give the direction of the fault properly, even though in so doing it is thrown somewhat out of its geographical relation. This fault enters Scott county near its north-western corner, whence it follows an almost straight line to the gap made through it by the North Fork of Clinch river, being crossed very near the head of Powder Mill gap by the Bristol railroad, and by the Jonesville and Estillville road at barely two miles from Pattonsville. It is crossed but once by the North Fork of Clinch.

This is probably the most violent of the faults observed within the region examined. The rocks on both sides of the fracture are bent upward, and, at more than one locality, the structure is distinctly that of a cracked anticlinal. The energy of the lift varied, for along a very considerable dis-

* Proceedings of this Society, 1872.

tance, the Hamilton shales are the lowest beds exposed on the northerly side of the fault, while at several localities lower groups, even down to the Medina, have been brought up.

At the gap of North Fork of Clinch, the Hamilton shales are well exposed on the northerly side at some distance from the line of break, where they are abnormally thick, show a strike N. 80° E. mag. and are dipping toward the fault at 40 degrees. Some sandstones seen between these and the foot of Buckner's ridge may represent the Lower Helderberg, and the Clinton rocks are exposed at the foot of the ridge. Whether or not the succession is complete, was not determined, as the side of the ridge is deeply covered with debris; but fragments of quartzite-like white sandstone were seen, which bear much resemblance to the Medina sandstone as shown in Moccasin gap of Clinch mountain. The exposures are all poor and the Clinton was recognized only by its fossil ore. The probable structure is doubtless as represented in Fig. 5.

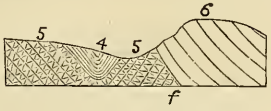

FIG. 5.—Probable structure of Hunter Valley fault at North Fork gap. *f*, Hunter Valley fault. Numbers as in Fig. 1.

The fault is crossed by the Jonesville and Estillville road at two or three miles further east. There the Hamilton shales, shown in the river "bottom," appear to be in contact with the calcareous sandstones of the Knox group, which form a bold wall along the line of fault. These shales are dipping toward the fault, but they may be folded as they are near the North Fork gap. At four or five miles further east, one has passed beyond the influence of the Pattonsville and Wallen Valley faults, and has reached the southerly foot of Powell mountain in Hunter valley. Standing here at the railroad line, he can follow with his eye, the course of the fault in each direction, for it is marked by the low and sharply serrate ridge known as Buckner's ridge. This seems to follow an almost straight line from the county line to the North Fork gap.

In the Hunter valley, the wall of Knox sandstone is as well marked as it is along the North Fork of Clinch, while on the other side the Quinnimont group covers the slope of Powell mountain and extends into the valley. Near the end of the valley, the North Gap structure is repeated, but only the Lower Carboniferous and the Devonian are turned up. Beyond this, no exposures exhibiting the structure were seen until Stony creek was approached. The sandstone wall is distinct all the way, but the debris from the conglomerates covers the whole "bottom" deeply even to the foot of the wall. Toward Stony creek, the structure becomes very similar to that observed in the North Fork gap, but time did not admit of working out its details. The Lower Carboniferous, the Devonian and the Silurian as far down as the Clinton at least, were recognized on Stony creek between the last exposure of the Quinnimont series and the wall of Knox sandstone.

The general structure, then, must be as represented in Fig. 6, which shows also the structure of Powell mountain. The Quinnimont series caps the

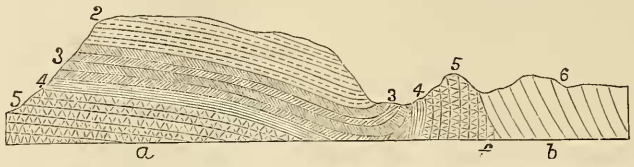

FIG. 6.—Cross-section along Stony creek through Powell mountain and Buckner's ridge. *a*, Powell mountain; *b*, Buckner's ridge. Numbers as in Fig. 1.

bluff overlooking the valley of South Fork of Powell river. Thence for several miles the dip is gentle, but within somewhat more than a mile from the fault it suddenly increases, becoming rather more than 30 degrees, and at the last exposure of the rock it is nearly 45 degrees. This change in rate is so abrupt that where the narrow valley follows the line of change, a fracture at once suggests itself as the only explanation of the condition.

It is altogether probable that a close, sharp fold exists within two or three miles south-east from the Hunter Valley fault. The shales alongside of Clinch river above the mouth of Stony creek are violently twisted and the plications are as close as those frequently seen in Archæan schists. The shales themselves in many places are jointed and have an indistinct slaty cleavage; but they show no other signs of metamorphism. The rock forming the bluff on the opposite side of the river is a pyritous sandy limestone very like that which is at the base of the Knox group. A similar condition was observed in crossing Buckner's ridge along the Jonesville and Estillville road, at probably fourteen miles west from Stony creek.

Copper ridge lies on the southerly side of Clinch river, until within six miles of the Tennessee line, where it is crossed by that river. It is a monoclinal, but the dip is irregular, as is shown along the Stony creek road as well as along the road leading from Gray's ford on Clinch river to Nickelsville on the southerly slope of the ridge. The dip at Clinch river is not far from 40 degrees; at two miles from the river, the beds are almost horizontal; but toward the southerly side of the ridge, the dip increases to almost 33 degrees. The only rocks exposed in this ridge belong to the Lower Silurian groups. Prof. Lesley, on the map accompanying his memoir on Wise and Tazewell counties, colors Clinton along the southerly side of this ridge; but no Clinton is present within Scott county.* The structure of the ridge in this county suggests the possibility that, at no great distance eastward, the ridge may consist of a double anticlinal with a shallow synclinal along the crest, in which some Upper Silurian rocks may be held.

The Copper Creek Fault, as appears from Prof. Lesley's map, extends for a considerable distance into Russell county, which adjoins Scott on the north-east. It was examined by the writer very near the Russell county

* Prof. Lesley did not visit this portion of Scott county.

line; also where the Estillville and Stony creek road crosses Copper creek; and in the Clinch river gap. This fault continues into Tennessee; it brings up the base of the upper division of the Knox group against the higher beds of the Trenton and Nashville group. *Moccasin ridge*, lying between Copper and Moccasin creeks, and owing its existence to the Copper creek fault, is a monoclinal with a dip throughout of little more than 30 degrees. It consists of rocks belonging to the Lower Silurian. Moccasin valley, eroded by the creek of the same name, separates Moccasin ridge from Clinch mountain, in which one finds a continuation of the series. The upper shales of No. III are shown on the northerly side, while the Medina sandstone forms the crest. Southerly dips continue beyond the crest of Clinch mountain, across the Poor valley and to the southerly side of Brushy mountain, where one reaches the

Fault of the North Fork of Holston.—Along the line of the Bristol railroad, this fault is reached at about three miles from the river, the distance being measured along the shortest line; but it is at somewhat more than six miles by the railroad. Near the Tennessee line, it is little more than one mile from the river at the mouth of Moccasin creek. It extends for a long distance toward the north-east and reaches into Tennessee. This fault is not inferior to the Hunter Valley fault, for it brings up the middle division of the Knox group against the very top of the Lower Carboniferous. But it shows none of the complex structure seen along the Hunter Valley fault. Wherever examined, the Lower Carboniferous rocks dip toward the fault and are not turned up near the line of fracture. There is, however, some crumpling at a little way from the break. A synclinal was seen on the North Fork of Holston at but a little way above the mouth of Moccasin creek, and an anticlinal is described at a little way further south-east. The same condition was seen along the railroad line beyond North Fork of Holston. Abrupt changes of dip occur in the Lower Carboniferous rocks along several lines in Brushy mountain.

The Walker Mountain fault follows the northerly side of that mountain and brings up the base of the Knox group so as to be in contact with the top of the Trenton and Nashville group. This fault extends for at least eight miles. No study of structure was made between Walker mountain and Bristol, where the line of section ended. In all probability, however, a small fault occurs in that interval, for the cherty beds at the top of the Knox group occur in the immediate vicinity of Bristol.

The extent of the several faults is approximately as follows:

1. *Fault of Poor valley*..... 2400′
2. *Wallen Valley fault*..... 2800′
3. *Pattonsville fault*..... 500′
4. *Hunter Valley fault* or *Clinch River uplift*..... 8000′
5. *Copper creek fault*..... 3000′
6. *Holston fault*..... 7500′
7. *Fault of Walker mountain*..... 3000′

The Holston and Hunter Valley faults were much greater originally, for

the Coal Measures, without doubt, covered Powell Mountain at one time, and it is equally probable that both the Quinnimont series and the Coal Measures existed at one time on Brushy mountain. It is altogether probable that on some of the high knobs of Brushy mountain, the Quinnimont beds have been spared by erosion. In such case, the extent of the Clinch river uplift would be not far from 10,500 feet and that of the Holston uplift very nearly 11,000 feet.

Poor Valley ridge is crossed by the South Fork of Powell river, by Powell river itself and by the North Fork: Wallen's creek crosses the Wallen Valley fault; the Clinch River uplift is crossed by the North Fork of Clinch, by Stock creek, by both branches of Cove creek and by several forks of Stony creek; Copper creek fault is crossed by Clinch river, and Copper creek in its windings crosses it several times; the Holston fault is crossed by a stream entering the river near the mouth of Moccasin creek and by Abraham's creek; while the Walker Mountain fault is crossed by the stream along which the railroad passes through the mountain.

II. General Description of the Groups.

The section exposed within the region examined extends from the Coal Measures to the base of the Knox group as recognized by Prof. Safford in Tennessee. Lower rocks are reached in the Great Valley of Virginia, which is drained by the South Fork of Holston river, but the reconnaissance stopped at Walker mountain on the northerly side of the Valley. Some of the groups show peculiarities not observed by Profs. Lesley and Fontaine in the area further east or by Prof. Safford in Tennessee.

The Upper Carboniferous.

The Upper Carboniferous is represented by the Coal Measures and the Quinnimont group or Seral (Pottsville) Conglomerate.

The Coal Measures.

The Coal Measures are found north from Stone mountain, and extend beyond Black mountain into Kentucky. Their thickness, as determined partly by estimate but mostly by barometric measurement, is not far from 2000 feet along Roaring Fork of Powell river and its tributary, Calahan's creek; but the highest part of Black mountain was not reached, since, according to Mr. Moore's barometric determination, the summit of that mountain at the head of Looney branch is 2200 feet above the Poor branch of Cumberland river; so that the thickness of Coal Measures is not less than 2500 feet, or somewhat less than that observed in the south-western part of Pennsylvania. There was no opportunity during the recent reconnaissance to complete the detailed section of these measures, and the highest 500 feet of the section given in the former memoir still remains unexamined in detail.

This area is not more than ten miles wide, for, according to the report on Mr. Moore's reconnaissance, already referred to, the Coal Measures are

cut off in Kentucky by the Pine Mountain fault. The basin begins in Tennessee, where it forms Prof. Safford's north-eastern division of the coal-field, and occupies the high lands of Morgan, Anderson, Scott, Campbell and Claiborne counties, north from the Emery river and east from a line passing through Huntsville and Montgomery. Prof. Safford found there 2100 feet of measures, in which *nine* beds of *coal* were seen, varying from one to six feet in thickness. These beds of the north-eastern district are, in part at least, above those of the other districts of the Tennessee coal-field, which belong not to the Coal Measures, as understood in other States, but to the Quinnimont group of Fontaine, which is equivalent to the Seral Conglomerate of Rogers.

No junction was made in the Wise county coal-field between the work done by Prof. Lesley and that done by the writer ; a gap of five miles remains yet to be filled. But there is no reason to doubt that, for the most part, the beds described by Prof. Lesley belong to the Coal Measures, and not to the Quinnimont group ; as, indeed, Prof. Lesley has suggested. His hesitation with reference to their exact position arose in measure from the coarseness of the Coal Measures sandstones, some of which are decidedly conglomerate.

The section observed on the headwaters of Powell river contains twenty-one coal beds, seen, varying in thickness from three inches to almost fifteen feet. No limestone was found in the section, aside from a few nodules, and those are ferruginous. The prevailing rock is sandstone, and the shales, a small part of the column, are almost invariably sandy. The sandstones vary from fine-grained to conglomerate, with pebbles rarely larger than a chestnut, and usually not larger than a pea. The thickness of the lower or productive portion is about 920 feet.

As the available coal occurs in what is equivalent to the Lower Productive Coal series of Pennsylvania, it might be supposed that valuable beds should be looked for in the upper part of the section, where the Upper Productive Coal series of Pennsylvania ought to be represented. It is not likely that any such beds will be found. The coal beds of the upper group lose their importance southwardly and southeastwardly, so that, for example, the *Pittsburgh bed,* which in south-western Pennsylvania attains to a thickness of from 9 to 12 feet, becomes thin and poor on the Kanawha river of West Virginia. The diminution in thickness and deterioration in quality is so regular along the line of nearly 200 miles, that there is every reason to believe that it continues southward until the bed becomes utterly worthless.

Some of the coal beds in this field are of decided excellence, showing barely one-half of one per cent. of sulphur, and from .75 of one per cent. to less than 4 per cent. of ash. One large bed yields an excellent coking coal, which will prove of immense advantage in the development of the iron ores in south-west Virginia and north-west North Carolina.

The Quinnimont Group or Seral (Pottsville) Conglomerate.

This group was observed along Stone mountain from the Little Stone gap to beyond Pennington's gap, and Mr. Moore describes it as making

part of that ridge to beyond the Tennessee line. Its beds are thrown over at a high angle, varying from 80 to 90 degrees, and its area is not materially wider than the thickness of the group. The same group occurs also on the easterly portion of Powell mountain.

This group is not far from 1000 feet thick, and is made up of sandstones, shales and coal beds. The highest stratum is a sandstone, known as the "Bee rock," which is about 135 feet thick, and is a marked feature along the northerly side of Stone mountain from Little Stone to Pennington's gap. This bed is more or less conglomerate. The lowest bed, also, is conglomerate, and is about 45 feet thick. Sandstones and conglomerates prevail, and some of the latter are very coarse. Six coal beds were seen in Pennington's gap and a seventh was found on Powell mountain.

The coal beds are variable in thickness, and in the quality of their coal, so that none of them attains to real economic importance. Those in Stone mountain have suffered severe crushing, and are apt to be pockety. The best is that which immediately underlies the "Bee rock," and varies from one to three feet. The same bed is even more irregular on the southerly face of Powell mountain, where its thickness is from 2 to 14 inches. A second bed of workable thickness was seen in Powell mountain, but it is concealed in both Big Stone and Pennington's gaps. This, at not far from 350 feet below the top of the group, is from 2 to 3 feet thick, and seems to hold a place very nearly like that which is mined for coking at Quinnimont. In Powell mountain, however, the coal is sulphurous, and can be used only for domestic purposes.

The coal beds in the greater part of the Tennessee coal-field belong to this group, and, without doubt, much of the section obtained in the north-eastern district of that coal-field should be referred to the same horizon, as Prof. Safford has done. The coal beds there are somewhat variable. A noteworthy feature of this group in Tennessee is that the bottom plate of conglomerate is absent, and the Coal group passes directly into the Lower Carboniferous.

The Lower Carboniferous.

The two divisions of Lower Carboniferous recognized in Tennessee by Prof. Safford, and named by him the *Mountain Limestone* and *Silicious* groups, are fully represented here. These names are used in this memoir in preference to those now used in Pennsylvania, because in this region, the old division of Lower Carboniferous into Umbral and Vespertine or Nos. XI and X would place all the limestone together, and thereby do violence to the actual relations of the beds.

The beds of this series are well shown along Stone mountain; on the bluff of Powell mountain overlooking the valleys of North Fork of Clinch, and the South Fork of Powell river, and in Brushy mountain near the North Fork of Holston river.

The Mountain Limestone Group.

This group exhibits some surprising variations. Along Stone mountain, the section as shown in Pennington's gap is

1. Shales and sandstones, with some thin limestones.... 705′
2. Limestones and calcareous shales .... 150′

under which comes the massive limestone of the Silicious group. But in Brushy mountain, where the exposures are almost complete, the section is:

1. Shales and sandstones, with thin limestones..... 800′
2. Limestones and calcareous shales..... 1470′

No measurements were made on Powell mountain, but the thickness of the group is not materially different from that shown in the Stone mountain gaps. The succession is complete on the Holston, and the exposures are so good that there is not the slightest reason to suspect a fault; as, indeed, will be apparent to any one who will consult the detailed section given in the chapter on the Holston area. The shales and sandstones on top are more or less calcareous; some of the sandstones are almost sky-blue, and they break with an irregular fracture; others are calcareous grits, but there are some which are comparatively soft. Several beds are used for the manufacture of hones and grindstones. This part of the group is well shown in Pennington's gap, when the river is low. It is exposed also in the Wolf creek gorge, which is followed from Holston river by the Bristol Narrow Gauge Railroad.

The greater part of the lower division in Stone mountain consists of calcareous shale, there being comparatively little limestone; but in Brushy mountain, there is very little shale, and many of the limestone beds are remarkably free from foreign matter; chert occurs in small quantity in some of the lower beds both in Stone mountain and near the Holston.

Fossils characteristic of the *Chester* limestone occur plentifully in some beds at all localities. *Pentremites godonii, Productus semi-reticulatus* and an undetermined *Zaphrentis* were found in Hunter valley; *Productus semi-reticulatus, Hemipronites crassus, Spirifera leidyi, Athyris subquadrata, Cyrtoceras, Fenestella* and *Zaphrentis spinulifera* were obtained in Pennington's gap; in Brushy mountain the stems of crinoids and *Chonetes* are common in some of the shale beds of the upper part of the group. The higher limestones are made up mostly of a *Fenestella*, with occasionally a *Zaphrentis* or a *Productus;* while in the lower limestones crinoid stems, *Fenestella, Zaphrentis, Productus cora, Productus elegans, Spirifera leidyi, Athyris subquadrata, Pinna missouriensis?*, and *Allorisma* are very common, along with other forms not recognized during the hurried examination.

The Silicious Group.

In Tennessee, according to Prof. Safford's statement, this group is double, consisting of

1. The *Lithostrotion* or coral bed, a cherty limestone, fossiliferous and everywhere characterized by *Lithostrotion canadense.*

2. The Lower or Protean member, variable, mostly silico-calcareous; often limestone; often sky-blue; contains much chert in its middle and lower portions; sometimes beds of crinoidal limestones.

This division is easily recognized in middle Tennessee, but the distinction is not so clear in eastern Tennessee. "So far as its presentation in East Tennessee is concerned, no division is practicable."

Within the area under consideration, the group is double. It is shown in the gaps of Stone mountain and is well exposed near the North Fork of Holston river along the line of the Bristol Narrow Gauge Railway Company. The section at Pennington's gap is:

1. Cherty limestone..... 200′
2. Reddish silicious beds, some of them blue on fresh surface, some shale..... 150′

The lower member was identified by Mr. Moore, who has visited this gap, with the Protean member or the Knobstone of Kentucky. The limestone is well exposed both here and in Big Stone gap, and at both localities it contains much chert in nodules, sometimes as large as a melon. The change in this group is as striking as that observed in the Mountain Limestone group, and the section near the North Fork of Holston is as follows:

1. Limestone and shale..... 655′
2. Calcareous sandstone and shale..... 100′

Several of the limestone beds hold very much chert, in layers and nodules, but the quantity is comparatively small in the lower beds, one of which is almost free from it. The lower member of the group consists of sky-blue grits, breaking with irregular fracture, and some yellow shales in which is a carbonaceous layer. The exposure is not wholly complete and between 30 and 40 feet of the upper part of the shale is concealed. The top layers for about 10 feet are fairly well shown in the railroad side-cutting. A *coal bed* may belong in the concealed interval as *coal* is said to have been digged in the bed of the river almost directly opposite to this concealed space.

The only trace of fossils found in the lower member was a fragment of what seemed to be *Leiorhynchus;* no *Lithostrotion* was seen in the upper member, but *Productus* and *Athyris* are common, as are also crinoid stems and bryozoans. These may be collected either in Stone or in Brushy mountain. The chert often replaces *Productus.*

The Protean member of the Silicious group shows some interesting variations; Prof. Fontaine obtained the following section on the Greenbrier river of West Virginia:

1. An upper member consisting almost entirely of red marlites..... 250′
2. A middle member characterized by predominance of gray sandstones, containing *coal*..... 350′
3. A lower member, characterized by silicious sandstones and conglomerate. Thickness exposed, 60′. With this should probably be counted 500′ of underlying more silicious flags, total..... 560′

There is no room for doubting the identity of this section with the Protean group, for Prof. Fontaine obtained *Lithostrotion canadense* from the lime-

stone near Lewisburg, West Virginia. The red shales underlying the limestone unquestionably belong not with the limestone, but with the underlying shales and sandstones. In Brush mountain and its vicinity in Montgomery county, Prof. Fontaine found:

The upper member	1090′
The middle member	670′
The lower member	930′

In all 2690′ instead of 1160, as on the Greenbrier river. *Coal beds* occur in both sections. But when the line of the Bristol Railroad is reached in Brushy mountain very near the border line between Scott and Washington counties, this great mass has diminished to barely 100′, its *coals* have disappeared and there remains of it nothing but some shales and shaly sandstones, most of them more or less calcareous. In eastern Tennessee the distinction between the Protean and the Upper member is obscure, owing probably to increase of limestone in the lower member.

The Devonian.

This is represented by the Chemung and Hamilton. The Coniferous and Catskill are absent.

The full section of the Devonian was seen only in Brushy mountain and the Poor valley between that and Clinch mountain. The first ridge of Brushy mountain is composed of Devonian rocks, and very fair exposures of the series can be found along lines running from the foot of Clinch mountain through the numerous gaps in that ridge. The succession is

Chemung	300′
Hamilton	830′

But in the Poor valley of Stone mountain and along the face of Powell mountain, the Chemung and much of the Hamilton are wanting, so that the rocks of the Silicious group rest directly on the lower Hamilton shales.

The Chemung, as shown along Brushy mountain, between Moccasin gap of Clinch and the railroad bridge over North Fork of Holston, consists of irregularly bedded sandstones and shales, containing more or less of nodular clay iron-stone and some dark shale. Fossils are not very numerous, but two thin layers associated with conglomerate bands show characteristic Chemung species, *Spirifera disjuncta* and *Productella boydii*, along with *Chonetes* and other forms which could not be obtained in good enough condition for identification. *Spirophyton* occurs plentifully in the lower beds. These rocks are well exposed along the railroad excavations between Mendota and the Holston bridge.

The Hamilton is triple, dark shales on top, yellow sandy shales in the middle, and black, more or less carbonaceous shales below; thus showing the general divisions observed in New York and Pennsylvania. All three of the divisions were seen in the Poor valley and Brushy mountain; but in the vicinity of Stone mountain and of the North Fork of Clinch river, only the lower black shales were found. The thickness of these near Stone mountain is probably not more than 125 or 150 feet, while at one locality it

is certainly less. The lower shales are often very rich in carbonaceous matter and two beds near the base have been mistaken for *coal* beds. Iron pyrites occurs plentifully in these lower shales at all localities and alum incrustations are common. A fine-grained, nearly white sandstone is shown at several places near the base of the group; it is a good firestone and has been hauled nearly forty miles by wagon, for use as furnace lining.

Few fossils were seen in the Hamilton; a *Chonetes* occurs plentifully in the upper shales and imperfect specimens of *Lingula* were found in the lower shales. These Hamilton beds are the black shales described in Prof. Safford's report on Tennessee.

The Upper Silurian.

This is represented by the Oriskany, Lower Helderberg, Clinton and Medina; the Niagara and the Oneida Conglomerate were not recognized.

The Oriskany.

This is a sandstone, probably not more than 35 or 40 feet thick, which is shown in the Poor valley of Powell river, and along the valleys of Wildcat creek and the North Fork of Clinch; also along the latter stream at the foot of Powell mountain, and in the Hunter valley at Stony creek. It is absent along the southerly foot of Clinch mountain, where, indeed, the Upper Silurian is represented only by the Medina and a small part of the Lower Helderberg.

The Oriskany sandstone is coarse, reddish on exposed surface but white on the fresh surface. It is friable, and at some localities, notably along the North Fork of Clinch river, it readily disintegrates on exposure. Very possibly the upper ore-horizon along Wildcat creek and the North Fork of Clinch river may belong in part to this sandstone. This rock contains *Streptorhynchus hipparionyx* on Stony creek; in the Poor valley of Powell river, it contains *Merista lata*, but with that there occur some forms belonging to the Lower Helderberg, so that in the writer's previous memoir the sandstone was referred to the lower group. The relation between the two groups is very close throughout this region.

The Lower Helderberg.

This group accompanies the Oriskany. In a general way its characteristics are very similar to those of the same group in New York. The *Leperditia* bed at the base is shown near Big Stone gap. Below this is a coarse sandstone like the Oriskany, which is shown at some localities along Powell river, and is well exposed along the line of the Pattonsville fault. The group closes with a limestone, which frequently becomes silicious. It is occasionally fossiliferous and the species are very characteristic.

The lower sandstone of this group is ferriferous and occasionally holds a brown hematite of excellent quality. A fossiliferous brown hematite was seen at the southerly foot of Clinch mountain, which, in all probability, should be referred to this group.

The Clinton.

Prof. Safford has found in Tennessee above the Clinton group a limestone, which he regards as representing the Niagara group of New York; but no traces of that limestone were observed by the writer, unless the fragments seen on the Jonesville and Gladesville pike and belonging in the concealed interval between rocks of Clinton, and those of Lower Helderberg age, may be referred to it. Elsewhere no bed was seen which could be regarded as representing the Niagara group.

The Clinton group is present in Poor Valley ridge; on both Wallen's ridge and Powell mountain; and at two localities along the northerly side of Buckner's ridge; but it is absent from the southerly side of Clinch mountain. The structure of that ridge is shown in Moccasin gap, where the Medina sandstone underlies the Lower Helderberg, on which the Hamilton shales rest.

No full section of the Clinton group was obtained, but its thickness cannot be far from 700 feet. The rocks are sandstones and sandy shales, but a calcareous sandstone, 60 feet thick, and containing thin bands of very fair limestone, occurs near the middle of the group. Three beds of the fossiliferous ore were seen, and, according to Mr. Pennington, who owns the forge in the gap which bears his name, two others exist, but they are very thin. The three beds belong below the middle of the group. The lower two are not far from 50 feet apart, but the interval to the upper bed is somewhat greater. These intervals show considerable variation in Poor Valley ridge, where the ore has been opened at several localities. Two beds were seen on the southerly slope of Wallen's ridge and three on Powell mountain; while only two are exposed in Hunter valley. The most important bed is the middle one, which usually carries excellent ore. The others vary much in thickness and quality of the ore.

The Medina Sandstone.

This is a salient feature of the region, as it forms the crest line of Wallen's ridge, Powell mountain and Clinch mountain. For the most part, it is a massive, fine-grained and very hard sandstone, but it has some layers of conglomerate, which are most numerous near the top. On Clinch mountain it is divided by bands of shale in which brown hematite occurs. On Powell mountain and Wallen's ridge it graduates upward into a reddish sandstone which may represent the white oak sandstone of Prof. Safford's report, though the writer is inclined to regard it as part of the Clinton or dyestone group, the total thickness as observed on the several ridges does not exceed 400 feet. No fossils were seen other than casts of the characteristic fucoid.

THE LOWER SILURIAN.

This is represented by Formations II and III of the Virginia column. A more convenient division for description is that made by Prof. Safford into the Knox and the Trenton and Nashville groups. The Knox group in-

cludes all but the upper part of No. II, or the Chazy of New York, which is placed by Prof. Safford in his higher group.

These groups are exposed over a great part of the area; they are the surface rocks in the great Powell valley between Poor Valley ridge and Wallen's ridge; they are shown in the southerly side of Wallen valley and the northerly side of Powell mountain; they extend unbroken from the Hunter Valley fault to the crest of Clinch mountain; and again from Holston fault to the Valley of Virginia. Detailed study of these groups could not be made; they are faulted and folded in the most perplexing manner, so that in the course of a day's ride across the country one passes again and again over the outcrop of the same beds. But the general features of the higher group and the upper part of the lower can be worked out somewhat rapidly in Moccasin ridge, where the dip is apparently unbroken by a fault. The lower parts of the Knox group are shown in Buckner's ridge.

The Trenton and Nashville Group.

This embraces the Hudson, Trenton and Chazy groups of New York. It is well shown in Powell valley, in Wallen's valley, and on the southerly slopes of Copper and Moccasin ridges. A section was obtained in the vicinity of Estillville, Scott county, which is:

1. Shales with thin limestone, calcareous at base..... 755′
2. Limestones and shales..... 430′

thus giving a thickness of 1185 feet for the series. A detailed description is given in the chapter on the area drained by Clinch river. The thickness of the shales is nearly the same on the northerly side of Wallen's ridge, where they are well exposed. They are black and more or less fissile at the base, but higher up the color becomes brownish to reddish brown, and the rock is in thick layers. The change to the Medina sandstone is well shown on the crest of Powell mountain, where it is abrupt. A great limestone lies at the base of the group; it is massive, occurs in beds from 10 to 20 feet thick, which are separated by thinner beds of shale. Many of these limestone beds yield a beautiful marble, which is equal to any from the typical localities in Tennessee.

Fossils are abundant in many parts of the section.

The Knox Group.

As in Tennessee, this group is triple; the upper division, consisting of cherty limestones and dolomites, is well exposed in Moccasin and Copper ridges, the middle or shaly division and the lower, consisting of calcareous sandstones, are shown in Buckner's ridge and near Clinch river.

The section of the upper division, as obtained in Moccasin ridge, may not be complete, part of it having been obtained on one road and part of it on another; there may be a gap of nearly 300 feet. The estimated thickness is about 1750 feet. In the upper half the limestones are more or less dolomitic and contain much chert, so much, that in three great beds the chert predominates. These beds are ridge making, and they crown the summits

of the several subordinate ridges in both Copper and Moccasin ridges. Those cherty beds, too, are iron bearing, and each of them carries extensive deposits of brown hematite, some of which have been explored. The lowest bed of this division is a calcareous sandstone very similar to that at the base of the group.

The middle division consists mostly of shales, with which are beds of impure limestone, more or less silicious and varying from 2 to 10 feet in thickness. This is shown along Clinch river at many places as well as along Stock creek and along the Jonesville and Estillville road as it passes from the North Fork of Clinch river to the mouth of Stock creek.

The lower division is a mass of calcareous sandstone and sandy limestones with some shale, the whole containing great quantities of iron pyrites, which makes up fully one-fifth of the whole mass of some beds. This mineral occurs in irregular laminæ often one-fourth of an inch thick, which sometimes make a network on the exposed surface of the rock. This division is well exposed along the whole line of the Hunter Valley or Clinch uplift within the region examined.

The composition of the Knox group here is approximately as follows:

1. Limestones, shales and chert beds ..... 1750′
2. Shales and limestones ..... 1000′
3. Calcareous sandstones, pyriferous ..... 500′

Thus giving for the whole group a thickness of not far from 3250 feet.

III. Geology of the Area Drained by Powell River.

The important coal-field lying north from Stone mountain narrows rapidly westward owing to the convergence of Stone and Black mountains, so that, as far as Virginia is concerned, it practically disappears at but a little way beyond Pennington's gap. But the available area diminishes even more rapidly. The streams flowing from Black mountain become shorter, and have a greater fall, so that, as the beds dip toward Black mountain, the area above natural drainage is much smaller even proportionately on the waters of the North Fork of Powell than it is along those forks which unite at the head of Big Stone gap.

The previous memoir by the writer contained a section of the *Coal Measures* as they appear above Big Stone gap; but the lower part was given according to a rude estimate, while 500 feet at the top had not been examined in detail. As already intimated, the unexamined part at the top is much greater than is given in that section. As amended, according to observations at the head of Pennington's gap and according to Mr. Moore's barometric determination of the height of Black mountain at the head of Looney branch of Cumberland river, the section is:

1. Not examined ..... 800′
2. Sandstone and sandy shale ..... 200′
3. *Coal bed* ..... 0′ 4″
4. Sandstone ..... 30′
5. *Coal bed* ..... 1′ 5″
6. Sandstone and shale ..... 115′

7.	*Coal bed*	0′ 6″
8.	Sandstone	70′
9.	*Coal bed*	2′
10.	Fireclay with stigmaria	2′
11.	Sandstone	12′
12.	*Coal bed*	1′
13.	Sandstone	70′
14.	Shale	20′
15.	*Coal bed*	0′ 4″
16.	Sandstone	26′
17.	Shale	4′
18.	*Coal bed*	0′ 10″
19.	Ill-exposed, mostly sandstone	65′
20.	*Coal bed "Cannel seam"*	7′ 3″
21.	Sandstone	50′
22.	*Coal bed—Upper Splint*	3′ 6″
23.	Sandstone	70′
24.	*Coal bed—Lower Splint*	3′ 6″ to 4′ 6″
25.	Ill-exposed, mostly sandstone, some yellow shale	120′
26.	*Coal bed*	Blossom.
27.	Sandstone	70′
28.	*Coal bed*	1′
29.	Shale and sandstone	25′
30.	*Coal bed—Kelly seam*	2″ to 15′
31.	Sandstone	45′
32.	Shale	5′
33.	*Coal bed—Imboden seam*	8′
34.	Shale	6′
35.	Sandstone	35′
36.	Carbonaceous shale	0′ 4″
37.	Sandstone	70′
38.	*Coal bed*	1′ 6″
39.	Ill-exposed, mostly shale or shaly sandstone	60′
40.	*Coal bed*	18″ to 3′
41.	Sandstone	35′
42.	*Coal bed*	2′
43.	Sandstone	60′
44.	*Coal bed*	2′ to 3′
45.	Sandstone and some shale	80′
46.	*Coal bed*	3′
47.	Shale and sandstone	85′
48.	*Coal bed*, blossom seen, said to be	1′ 6″
49.	Interval concealed	125′
50.	*Coal bed*, not seen, said to be	2′
51.	Shale	25′
52.	"Bee rock" of Quinnimont group	
	Total thickness	2348′

As the important beds of this group were described in detail in the previous memoir, only a brief synopsis is necessary here. No additional information has been obtained respecting them, for the area drained through Pennington's gap by the North Fork of Powell river is wholly undeveloped, and only the lower coal beds are well exposed.

The *Cannel* seam consists of:

Cannel	2′	
Alternating layer of *coal* and shale	1′ 10″	7′ 3″
Bituminous *coal*	3′ 5″	

But the bed is variable and at another locality it shows three layers of *coal*, amounting in all to but 2 feet, distributed through 19 feet of measures. The *coal* from the *Upper Splint* is of superior excellence, containing but 3.075 per cent. of ash and but 0.406 of sulphur; the coal from the *Lower Splint* seems to be of equally good quality. The *Kelly* seam is a variable bed, which, where thickest, shows three divisions; the upper one is slaty, the lower one is a splint of fair quality, while the middle division seems to be a gas coal of remarkable excellence, as it contains 38.850 of volatile combustible matter, with 0.771 of sulphur and only 0.890 of ash.

The *Imboden* or coking seam is by far the most important. It was first traced by General J. D. Imboden, who made many prospecting pits in it to determine its value. This bed varies in thickness from 6′ 11″ to 8′ 5″, and everywhere yields a soft coal, which produces an excellent coke. The coal contains but 1.515 of ash and only 0.594 of sulphur.

Nos. 38 and 40 were seen only in Pennington's gap. The former is insignificant; the latter is badly distorted by pressure and the coal is so crushed as to be useless. The whole section from No. 37 to the bottom is vertical at the head of Pennington's gap. The coal bed, No. 42, has not been mined, but it is exposed in the bank of the North Fork, where it shows a clay parting midway. No. 46 is evidently the same with No. 44 of the section on p. 91 of the previous memoir. It shows nearly 3 feet of good coal on the North Fork, where some mining has been done. The coal is fat, caking and contains much mineral charcoal. The two beds, Nos. 49 and 51, were reached only in Pennington's gap, where they are no longer exposed.

Stone Mountain.

The structure of this mountain has been explained in another part of this memoir. The groups involved in the fold include the whole series from the Clinton up, but in the mountain as it now stands, one finds only the lower part of the Coal Measures, with the Quinnimont group and Lower Carboniferous. Exposures are very poor in both Little and Big Stone gaps, and the succession of the rocks could not be made out until Pennington's gap was reached. There the following section of the Quinnimont group was obtained, the thicknesses being estimated:

1. Sandstone "Bee rock,".....135′
2. Shale..... 15′
3. Sandstone..... 12′

4.	*Coal bed*	1′ 2″ to 3′
5.	Sandstone	20′
6.	*Coal bed* and shale	1′
7.	Sandstone	200′
8.	Conglomerate	100′
9.	Concealed	60′
10.	Sandstone	45′
11.	*Coal bed*	0′ 6″
12.	Shale, clay and sandstone	40′
13.	Flaggy sandstone	15′
14.	Massive sandstone	120′
15.	Concealed	45′
16.	*Coal bed* with much shale	5′
17.	Imperfectly exposed, much conglomerate	95′
18.	*Coal bed* and shale	1′ 8″
19.	Shale	20′
20.	*Coal bed* and shale	2′
21.	Clay	7′
22.	Sandstone	15′
23.	Pots of *coal* in sandstone	7′
24.	Conglomerate	45′
	Total	1009′ 2″

The rocks are vertical; but the gorge is very crooked and some difficulty was encountered in the effort to estimate the thickness of No. 7, which may be somewhat greater than is given above.

No. 1, the "Bee Rock" of Big Stone gap, forms a conspicuous comb along Stone mountain from Little Stone gap to certainly 3 miles west from Pennington's gap, and it is well shown at the head of each gap. The upper part is flaggy and rather fine-grained; but below, the rock becomes massive and coarser, with numerous pebbles. No bedding is perceptible for 65 feet from the bottom. Some plant impressions were seen and there is much carbonized wood in large fragments. The shales underlying this rock are brown to reddish brown, clayey and without distinct bedding. The sandstone, No. 3, is blue and flaggy in the upper part, but becomes gray and shaly below.

The *Coal bed*, No. 4, is much crushed and its thickness has been much reduced by the violent pressure. It is badly twisted and is from 14 inches to 3 feet thick. The coal is good, caking, admirable for blacksmiths' use and contains much mineral charcoal. The underlying sandstone is argillaceous and near the coal it is really a sandy fireclay containing many stems and rootlets of *Stigmaria*. The little *Coal bed*, No. 6, is but 5 inches thick and has black shale both above and below it.

No full exposure of the sandstone, No. 7, could be found. The mass varies from fine-grained sandstone to coarse conglomerate and holds some bands of shale. A *Coal bed* is said to occur in this interval, but no traces of it were seen. Nos. 8 and 10 are conglomerate. The latter crosses the

river at Pennington's mill and is well exposed immediately below the dam. It is light gray, cross-bedded and contains many rude impressions of plant stems. Some of its finer layers yield a good firestone ; and the lining of Pennington's forge, constructed of this sandstone, has stood for three years. This is said to bear a dash of cold water without cracking, even when at a bright red heat. The little *Coal bed*, No. 11, is of no value, but the clay underneath it makes excellent brick though it is too ferruginous to be used for firebrick. No. 13 is shown immediately below the forge and some of its layers do well as firestone. Much coarse conglomerate occurs in Nos. 14 and 17, and there are several coarse layers in No. 24. Many impressions of plant stems were seen in No. 22.

The *Coal beds*, Nos. 16, 18 and 20, are no longer exposed in the gap. They were opened by Mr. Pennington, but proved worthless. No. 16 was opened both in the bank of the stream and on the hillside ; it is 5 feet thick at both places, but the *coal* and shale are in nearly equal proportion and are so mixed that the bed is without value. A bed, shown on the ridge at about two and one-half miles from gap, is supposed by Mr. Pennington to be the same with No. 16. It is 2 feet 9 inches thick and yields good coal, of which some has been hauled to Jonesville.

The other beds consist only of a worthless commingling of *coal* and shale. No. 23 may have been a *Coal bed* at one time, but if so, it was torn up and re-distributed during the formation of the overlying sandstone, for now it consists of simply small pockets of pulverized coal scattered through 7 feet of sandstone.

The massive beds of this group project above the surface like dikes and some of them overhang the river.

The Lower Carboniferous limestone is well exposed at many places along Stone mountain, but continuous exposures were found only in Pennington's gap, where the following succession was made out, the thicknesses being estimated :

Mountain Limestone Group.

1.	Imperfectly exposed	40′
2.	Sandstone	15′
3.	Dark fissile shale	5′
4.	Sandstone	20′
5.	Imperfectly exposed, much shale	200′
6.	Sandstone	75′
7.	Shale with thin limestone	35′
8.	Sandstone	40′
9.	Concealed	60′
10.	Calcareous sandstone	120′
11.	Dark fissile shale	5′
12.	Calcareous shale	90′
13.	Argillaceous limestone, fossiliferous	15′
14.	Imperfectly exposed	60′
15.	Massive limestone	25′
16.	Calcareous shale, fossiliferous	50′

Silicious Group.

17. Limestone.....200′
18. Shale and sandstone.....150′

Total Mountain Limestone group, 855′; Silicious group, 350′.

The interval, No 1, is filled for the most part with shale, though there are traces of sandstone and a bed of rather lean carbonate of iron. The latter has been opened by Mr. Pennington, but it is too lean for use in his forge. The shale, No. 3, is quite rich in carbonaceous matter and it may represent the *Coal beds* of south-west Pennsylvania, belonging at this horizon. Nos. 2 and 4 are hard red grits. The interval, No. 5, contains some red shale, some bluish grit-like beds, but for the most part it is effectually concealed. The sandstone, No. 6, is fine-grained, mostly light colored, and the sand is sharp and cleaned. The bed is well exposed on both sides of Pennington's gap and is the first sandstone bed seen in ascending Big Stone gap. It is the principal source of the sand covering the "bottom" of Powell river and that of the North Fork near the gaps. No. 10 is a hard blue grit, containing not a little oxide of iron, which causes disintegration on exposure. It is well shown in the bed of the North Fork in Pennington's gap. No. 14 is imperfectly exposed, but here and there it shows some limestone and red shale. Mr. Pennington says that some good iron ore has been obtained from this interval. No. 15 is an excellent limestone, and it would be good either for furnace use or in the manufacture of lime. Chert first appears in the lower part of No. 16, where numerous layers were seen from half an inch to two inches thick and richly fossiliferous. From one of these the following species were obtained during a hurried examination: *Fenestella; Zaphrentis spinulifera; Productus semi-recticulatus; Hemipronites crassus; Spirifera leidyi;* and *Athyris subquadrata.*

The great limestone, No. 17, is well shown along the southerly face of Stone mountain from Little Stone gap to far beyond Pennington's gap; and it is well exposed in each of the gaps. The rock is mostly fine-grained and compact, with conchoidal fracture, though here and there a layer occurs which is somewhat granular. Some beds contain much chert in nodules occasionally as large as an orange. Fossils are numerous, but for the most part they cannot be obtained in identifiable condition. *Productus cora* with an unrecognized *Zaphrentis* was obtained near the mouth of Big Stone gap.

No. 18 has been identified by Mr. Moore with the Protean member of the Silicious group of Tennessee, the Knobstone of the old Kentucky reports. It is not very well exposed at any locality visited; but as far as seen, it consists of bluish sandstones, weathering reddish, with some shale. These sandstones are slightly calcareous and some of them are true grits. No fossils were seen in this stratum.

Poor Valley and Poor Valley Ridge.

Under this head may be included not only that narrow area between Stone mountain and the fault of Poor Valley ridge, but also the area

around the headwaters of the South Fork of Powell river and its tributary, Wildcat creek. This embraces so much of the region between Stone mountain and Powell mountain as is drained by those streams.

At the apex of this space, where Stone and Powell mountains come together, just east from Little Stone gap, one finds in the valley only the Hamilton shales. The gentle anticlinal, in which the fault of Poor Valley ridge originates, soon brings up the Oriskany, the Lower Helderberg, and, at a little way further west, the Clinton ore group. The ridge formed by the anticlinal and gradually developing fault is known here as Wallen's ridge and shows the Clinton group on both sides, with the higher groups at a little distance from the foot. No detailed section was made on Powell mountain, but the Hamilton shales are at its base; higher up is the Lower Carboniferous, forming a conspicuous band along the face of the mountain; while above it the Quinnimont group extends to the crest, whence it may be followed to the Hunter valley.

Along Wildcat valley and the southerly slope of Wallen's ridge, Upper Silurian rocks prevail, the Medina at the crest of the ridge, the Clinton lower down the slope, while the Lower Helderberg occupies the valley and here and there reaches some way up the side of the ridge. The Clinton ores are unusually good here, that from one bed showing 52.6 per cent. of iron with but 0.116 per cent. of phosphorus.* The Lower Helderberg shows two ore-horizons, of which the upper may belong in part to the Oriskany. The lower horizon has an unusually good brown hematite, with 52.55 per cent. of iron and only 0.051 per cent. of phosphorus. The pockets of good ore are separated by stretches of varying length, in which an enormous amount of brown hematite is seen, but so mixed with sand as to be altogether unavailable. Beyond all doubt the higher horizon carries much good ore, but the old workings, whence ore was obtained for a Catalan forge, have been filled up and only the silicious ore is exposed.

The Helderberg ores of Poor valley are of uncertain value. Some fair ore occurs at several miles east from Big Stone gap, but the most of that seen there is silicious and evidently belongs to the higher horizon. It contains many fossils characteristic of the Lower Helderberg. Further west, the ore seems to be wanting, no evidence of its presence having been observed at any exposure between Big Stone and Pennington's gap.

The best exposure of the Hamilton shales in the Poor valley is at a mile or so east from the Big Stone gap, where the rock seems to be thicker than it is further west. It is said to yield fossils there. The increasing strength of the disturbance westward makes the dip of these beds vertical before reaching Pennington's gap and exposures in that vicinity are not wholly satisfactory. The valley itself is very narrow until beyond that gap, where it opens up somewhat. No trace of Chemung rocks were found in the valley and the Lower Carboniferous rests directly on the lower black shales of the Hamilton.

*All analyses in this memoir, unless otherwise stated, are by Mr. A. S. McCreath, chemist to the Second Geological Survey of Pennsylvania.

No good section of the Clinton was obtained ; the partial one obtained near Big Stone gap and given in the previous memoir contains all the details yet secured. The ores of this group are easily followed along the valley and ridge. Three beds occur not far from Big Stone gap, but only one of them is really important. This, as exposed on the Horton property at say a mile and a half from the gap, shows :

Hard ore	4′ 8″
Soft ore	2′ 6″

The lower part of the upper layer for, say 20 inches, is a very fair ore, though inferior to that from the lower portion of the bed. This is the middle bed. The upper bed is shown in the bank of Powell river not far from the gap, where it is from 5 to 8 inches thick ; while the lower bed, as shown in Cedar gap, through Poor Valley ridge, contains little soft ore. The same beds are shown in the gap of Powell river through Poor Valley ridge and some of the ore from that locality has been reduced in Mr. Pennington's forge, where it proved good. Mr. Pennington has opened three beds of ore near his gap, but of these only the middle one is good. This shows :

Soft ore	4″
Clay	8″
Soft ore	25″

The clay is irregular and is said to disappear, so that the ore is sometimes fully 3 feet thick. The upper layer at this exposure is pebbly and the lower layer is equally so for an inch or two at the top ; but Mr. Pennington states that this is an abnormal condition and that the pebbles are rarely present. This ore is mined to supply Pennington's forge at which about 200 pounds of excellent iron are made daily.

Powell Valley.

Throughout this valley, which embraces the whole space between Poor Valley ridge and Wallen's ridge, one finds only formations II and III. The distinction between the groups was not made out in detail, for the structure is too involved to be worked in a reconnaissance. It is altogether probable that the magnesian beds of the Knox group occupy the northern side of the valley in the wider parts of the area. They lie close to the fault in the Turkey cove, while, nearer Wallen's ridge, the beds of the higher group are well shown and yield great numbers of characteristic fossils. Good localities for collectors were seen along the road crossing Wallen's ridge from Turkey cove, and along the Jonesville and Gladesville road in the cove. The magnesian limestones on Elk Knob are practically horizontal and weather into detached blocks and pillars, making the long summit of that hill a "rock city." Brown hematite of excellent quality is said to exist on Chestnut ridge in this valley ; and some of it has been tried with good results at Pennington's forge.

Wallen's Ridge and Valley.

At Turkey cove, the limestones of III rise high up on the side of Wallen's ridge, but the shales belonging at the top of the group are concealed along the road crossing the ridge. Further west, however, as the ridge is pushed away toward the south-east, the limestones reach only to its foot or to but a little way up its side. The shales are well shown along the Jonesville and Estillville road as it winds up the mountain. They are dark and fissile below but become somewhat sandy above. Thin irregular bands of limestone occur, all of which are fossiliferous. The thickness of the shales is not far from 700 feet.

The Medina sandstone is reached at the summit of the ridge, where, for the most part, it is fine grained and compact; but it contains some layers of shale and an occasional bed of conglomerate. Exposures are incomplete near the road, but the rock forms cliffs at two or three miles further east. The thickness, as estimated, is not far from 350 feet. The Clinton group is reached on the southerly side, where it is not well exposed. The fossil ores are shown at several places, but are best seen near the head of the valley, where Mr. Jerome Duft has explored them to a slight extent. The Lower Helderberg rocks are mostly concealed.

The Wallen Valley fault passes very near the southerly foot of Wallen's ridge, and is crossed by the Jonesville road at perhaps three-fourths of a mile from Wallen's creek. The exposures near the line of fault are very poor, but they suffice to show that the beds in contact with those of the Lower Helderberg belong near the top of the Knox group, for the soil has a deep red color and fragments of chert are scattered through it. The first satisfactory exposures are those of the Trenton and Nashville group, whose beds are well shown at Stickleyville and elsewhere along Wallen's creek. They are very fossiliferous, though the number of species found at Stickleyville is small. The following were seen:

Stromatopora; Chætetes petropolitana; Bryozoans; Strophomena alternata; Leptæna sericea; Orthis testudinaria; Orthis occidentalis; Orthis tricenaria?. The *Chætetes* is often replaced by chert, as is also the case on the northerly side of Elk Knob in Powell valley.

The limestones of this group continue nearly half way up Powell mountain, and, thence to the summit, the shales of the group are occasionally shown. The Medina sandstone is reached at the summit, where one looks down into the area drained by Clinch river.

As the Wallen valley fault disappears north-eastward, the outcroppings of Upper Silurian on the southerly slopes of Wallen's ridge and Powell mountain approach each other; and on the easterly face of the divide between Wallen's creek and the North Fork of Clinch, the two outcrops seem to have come together, as do the similar outcrops on Wallen's and Poor Valley ridges, where the fault of the latter dies out. No detailed examination of this divide was made, and the structure was ascertained only in so far as was possible in passing through Slemp's gap.

IV. Geology of the Area Drained by Clinch River.

The whole of this area lies within Scott county. For convenience of description, it may be regarded as divided by the road leading from Big Stone gap to the mouth of Stock creek. The easterly division extends from the crest of Powell mountain to that of Moccasin ridge, and is drained by several streams, to which reference will be made in their place; the other division extends westwardly to the Tennessee line and southwardly from the crest of Powell mountain to Clinch river. It is drained principally by Little Stock creek and the North Fork of Clinch river.

The Western Division.

The Medina sandstone is somewhat imperfectly exposed on the summit of Powell mountain along the Jonesville and Estillville road, but appears in cliffs at but a little way further east. Its junction with the shales of Formation III is well shown at the roadside, and is very sharp, there being no transition bed. The Medina, for 35 feet from the base, is massive, cross-bedded, and not at all conglomerate, though here and there a pebble appears. Impressions of *Arthrophycus*, though not abundant, are by no means rare. Some imperfect exposures of Clinton rocks were seen at about one-third of the way down the mountain slope and numerous fragments of fossiliferous ore lie scattered in the road and on the hillside. Only one bed, however, was found in place, and its ore is highly silicious. Further east along this slope of the mountain, three beds have been exposed on property lately belonging to the Kane estate, which are equivalent to the three beds seen in the Poor Valley ridge. The upper one is very thin, and its ore is silicious, but the middle and lower beds are of workable thickness and their ore is good, though evidently somewhat leaner than that from the middle bed of the Poor Valley ridge.

These ores extend along the mountain face quite to the head of the North Fork of Clinch river, whence they cross the divide and continue along the southerly face of Wallen's ridge along Wildcat valley; but no measurement of the group or of its ores was made in Slemp's gap or above it along the North Fork of Clinch.

Still further down the slope or very near the foot of the mountain are the Lower Helderberg and the Oriskany, beyond which come the shales of the Hamilton. A small tributary to the North Fork of Clinch flows along the foot of the mountain, and the road to Sneedville follows it. These rocks are exposed along this stream, and the shales are reached at Robinson's mill, where they are dipping almost southward at a high angle. At a little way below the mill, the stream enters a gap through a low ridge produced by the Pattonsville fault, and on the other side it joins the North Fork. At the entrance to the gap, one reaches the coarse sandstone, and the limestone at the base of the Lower Helderberg, both of which have been pushed to 5 degrees beyond perpendicular. Several exposures of Lower Helderberg rocks occur within this gap, but the section is not continuous.

On emerging from the gap made through this low ridge, the stream enters the North Fork, which there changes its course, and for a short distance flows irregularly along the strike. The road follows the right bank of the stream, and winds so as to be now in the Lower Helderberg, then in the Hamilton shales. The upper limestone of the Lower Helderberg is well exposed at the roadside, not far below the gap, where it underlies the Oriskany, which is ferriferous. The river changes its course near Mr. James Robinet's place, and breaks across the Hunter Valley fault (Clinch River uplift), whose course is marked by Buckner's ridge. The Hamilton shales are fairly well exposed here and are dark throughout. Those resting on the Oriskany are richly carbonaceous, and films of *coal* are common in one layer, which is nearly 18 inches thick.

No rocks newer than the Hamilton shales are shown between the crest of Powell mountain and Buckner's ridge, as far, at least, as two miles west from the North Fork gap in the latter ridge. If the Pattonsville fault were absent, there would be ample room for the Lower Carboniferous groups, which, indeed, are present on Powell mountain in the other division of this area. A material change in the character of this fault must take place at not far from the gap, for Prof. Safford's map shows that the Lower Carboniferous groups are present at the State line both on the slope of Powell mountain, and on the ridge marked by the Pattonsville fault.

The gap of North Fork of Clinch exhibits the complicated structure of the Hunter Valley fault or Clinch River uplift. The pyritous calcareous sandstones, belonging to the base of the Knox group, form a bold ridge with the rocks dipping southward at almost 50 degrees; but at the base of the cliff on the northerly side, a considerable mass of limestones, reddish and white sandstones was seen. This is not less than 150 feet thick. Behind it is an imperfectly exposed interval between the base of this bluff and the last exposure of Hamilton shale, in which are fragments of sandstone not unlike the Oriskany. This mass is covered with débris and the succession of its beds could not be made out. Unsuccessful search was made for fossils. A conglomerate of rounded quartz pebbles bound by red hematite occurs here, and bears much resemblance to the Clinton ore; with it is a ferruginous sandstone, which, when casually examined, appears to be an iron ore. It is, however, merely a very fine-grained ferruginous sandstone. This is shown on both sides of the gap, and the apparent amount of ore is very great. But the material is utterly worthless as appears from Mr. McCreath's analyses; No. 1 being the conglomerate, and No. 2 the ferruginous sandstone.

Metallic iron	12.050	11.550
Sulphur	0.052	——
Phosphorus	0.862	——
Insoluble residue	69.400	——

This was worked many years ago in a forge, whose ruins still remain in the gap.

Returning now to the Jonesville and Estillville road, one finds the Lower

Helderberg, Oriskany and Hamilton as at Robinson's mill on the Sneedville road, and the little village of Pattonsville stands on the Hamilton; but the Pattonsville fault is crossed by that road immediately beyond the village and the Lower Helderberg is brought up as in the gap below Robinson's mill. The Oriskany sandstone is reached again near the "bottom" of North Fork of Clinch and varies in color from rusty yellow to dingy white. The rock is very friable and it must be somewhat calcareous, as the surface has given way at many places, showing the presence of caverns beneath. The hills are covered with loose reddish yellow sand, derived from this rock. Both the Lower Helderberg and the Oriskany sandstones are fossiliferous but the fossils are very obscure. Brown hematite occurs on the Pattonsville ridge and is continuous up the North Fork of Clinch. No analyses of this ore have been made, but the quality seems to be good. The Hamilton shales are continuous to the wall of Powell mountain in the other division of this area and are fairly well exposed at many places. Here, as at many other localities, they are supposed to hold *coal.*

Ascending the North Fork one reaches the strip of Lower Helderberg rocks in Slemp's gap near Ward's mill, and the upper limestone of that group is well shown at but a little way above the mill. These rocks remain in sight on both sides of the road until the summit between Clinch and Powell is reached. The Oriskany was not seen here, its place being concealed.

Returning again to the Jonesville and Estillville road, one crosses the Hunter Valley fault and enters Buckner's ridge at probably 2 miles from Pattonsville. An ill-exposed space of about 10 yards exists here, but there seems to be no reason to suppose that any rock lower than the Hamilton shale is brought to the surface. The Robinet "ores" are clearly absent.

In Buckner's ridge the calcareous sandstones and silicious limestones at the base of the Knox group have a dip of 45 degrees, which soon decreases to 30 degrees. With these are thin beds of shale, and the whole thickness is not far from 500 feet. Above this series are shales with irregular beds of impure limestone, in all about 1000 feet thick. These are followed by massive limestone, some of it dolomite, which extends beyond the divide and appears on the waters of Little Stock creek. The exposures are indistinct beyond this divide, until at some distance one comes to shales which bear close resemblance to those which rest on the calcareous sandstones. These shales are well shown along Little Stock creek, which flows between them and the massive magnesian limestones. The shales are badly twisted. The creek flows through a tunnel in the limestone, which is not far from 600 feet long, and from 10 to 15 feet high.

Few observations were made in Big ridge, the continuation of Copper ridge beyond Clinch river. The rocks are the same as those seen in Copper ridge and it is altogether probable that the reports respecting the occurrence of iron and manganese ores are true. One may not do more than to assert the mere occurrence of these ores, as nothing has been done to determine the extent of the deposits.

The Eastern Division.

The gradual disappearance eastward of the Pattonsville and Wallen Valley faults has permitted the retention of much newer rocks on the eastern than on the western part of Powell mountain; so that on the former the Quinnimont group and not the Medina sandstone forms the crest of the ridge.

Powell mountain has an abrupt slope on the north-westerly side, and the face toward Slemp's gap is so steep that it can be climbed only with great difficulty. The succession of the rocks on these bluffs is distinct, the Quinnimont group forming the rim, with the Lower Carboniferous, the Devonian and the higher beds of the Silurian in order below it. No detailed section was made here, but the Chemung, if present, must be extremely thin, and the probabilities are altogether in favor of the conclusion that it is wholly wanting.

The Hamilton shales are well shown on the road following the foot of Powell mountain and they contain carbonaceous bands in which thin streaks of *coal* occasionally occur. One of these was seen at barely half a mile below Ward's mill. The Lower Carboniferous rocks make a well-defined band, curving round the end of the ridge in Slemp's gap and continuing to immediately beyond Powder Mill gap, terminating where the Hunter Valley road leaves the line of railroad. The Mountain Limestone group is exposed near the school-house not far from the railroad, where it contains *Pentremites godonii, Zaphrentis, Productus semi-reticulatus,* and *Chonetes.* The Hamilton shale is shown between it and the calcareous sandstone of the Knox group, turned up by the Hunter Valley fault or Clinch River uplift. No traces of any lower rocks were observed between the limestone and the line of fault.

The rocks of the Knox group form a sharp, though low ridge, which is continuous into Russell county. The Hunter Valley road lies behind the ridge and soon rises upon the Quinnimont rocks, which seem to be in contact with the beds on the opposite side of the fault. This, probably, is not the case, but the coat of débris between the last definite exposures of the conglomerate and the base of the sandstone wall is so thick as to conceal everything.

Coal blossoms have been seen in all the hollows leading from the northern side of Hunter valley into Powell mountain. Some *coal* has been obtained along the Laurel Fork of Stock creek, at probably two-thirds of a mile from the valley, but the gorge is so close and rugged, that the coal can be brought down only by packing it on men's shoulders. In a bed which has been opened along the main stream at only a few yards from the road, the coal is decidedly good, being preferred to all others by blacksmiths; but the bed is badly distorted and crushed. It stands at an angle of 45 degrees and varies in thickness from 2 inches to 14 inches within a distance of two or three feet. The sharp dip prevails to nearly half a mile from the valley, where it changes suddenly and becomes not more than 5 or 6 degrees. At

say a mile from the road, Mr. Horton has opened a bed on Stock creek, where the exposure is:

Sandstone	20′
Shale	5′
Coal bed	2′ to 3′
Clay, seen	0′ 8″

The roof is very insecure, the shale being slickensided in nests, and a serious fall was seen at 30 feet from the mouth of the pit. The coal is regular, shows no signs of crushing such as those observed in the higher bed and is an excellent fuel for domestic use. It contains a good deal of pyrites and blacksmiths complain that they need much borax when using this coal. Not a little mining has been done here and some of the coal has been carried to Estillville, nearly 20 miles away.

The higher bed is evidently the same with that seen in Pennington's gap under the "Bee Rock." Its characteristics and those of the rock above and below it are the same with those observed in that gap. The lower bed is not shown in the gap and it must belong somewhere in the ill exposed interval, No. 7 of that section, as bold cliffs of conglomerate were seen below it. The interval between the two beds cannot be determined without careful instrumental measurement.

The upper bed has been opened by Mr. H. Stone at about a mile further up Hunter valley. His pit has fallen in and the bed is concealed, but its features as described by Mr. Stone are similar to those observed at Mr. Bailey's pit. Coal blossoms occur at several places on Cove creek, a tributary to Clinch river flowing from the valley across the fault; but no attempt has been made to ascertain either the thickness or the quality of the coal. Mr. Pinckney Carter has opened two beds on Stony creek. The upper of these is in all probability the same with that opened by Mr. Bailey and Mr. Stone, and it is exposed on Stony creek at somewhat less than one-fourth of a mile above Mr. Carter's house. It resembles a pocket rather than a bed and dips at somewhat more than 30 degrees. The opening extends along the face of the cliff for about 35 feet; the *coal* is three feet thick at the thickest place but pinches out on each side to nothing. More than 10,000 bushels of coal are said to have been taken from this clumsy pit and packed down a rocky trail by the diggers. The *coal* is excellent for blacksmiths' use. Another bed, at probably 300 feet further up the stream calculating in the direction of the dip, is 2 feet thick. A third bed, also about 2 feet thick, which is shown at say one-fourth of a mile up the left hand fork of the creek, has but an insignificant dip. The several openings seen along this stream probably belong to this bed.

Clay iron-stone occurs in moderate quantity in the shaly beds of the Quinnimont group, but there is not enough to be of economical importance.

The peculiar structure of the Hunter Valley fault in the vicinity of Stony creek has been explained in another part of this memoir. The fault appears to be simple until within less than two miles of that creek, and the only

rock shown at the base of the Knox wall is some Hamilton shale. But at Mr. Boatwright's place on Stony creek, the Lower Carboniferous, Hamilton, Oriskany, Lower Helderberg and Clinton were all recognized between the Conglomerate and the Knox group. These seem to come in reversed order as already explained.

The exposure on Mr. Boatwright's property is good. Two beds of the Clinton ore were seen there, which represent the upper and middle beds of the Poor Valley ridge. The upper bed is silicious and no special investigation of it was made. The other was exposed to a thickness of 2 feet for examination and it is said to be 6 feet thick in an excavation now filled up. But this thickness is doubtless an exaggeration, and the excavation may have followed the dip, which is abrupt. *Leptocœlia hemispherica* was recognized in this bed. The ore analyzed by Mr. McCreath yielded :

Metallic iron	43.650
Sulphur	0.008
Phosphorus	0.101
Insoluble residue	31.480

The Lower Helderberg brown hematite is exposed at several localities here on both sides of Stony Creek valley. Samples of the ore analyzed by Mr. McCreath showed :

Metallic iron	41.375
Sulphur	0.060
Phosphorus	0.890
Insouble residue	22.200

But it is clear that the samples from this bed are not altogether fair, as the yield in a forge seems to have been greater than the amount of iron shown by analysis. This ore was digged to some extent for use at the forge on Moccasin creek near Estillville ; but the diggings were abandoned many years ago and the samples were taken from loose pieces which had been weathering for probably 20 years. The limestone of the Lower Helderberg is very fossiliferous and its species ally it closely to the Delthyris Shaly Limestone of the New York group. The Oriskany sandstone is well shown and contains *Streptorhynchus hipparionyx*.

There is little of interest between the Hunter Valley fault and Clinch river. In descending Stock creek, one finds himself constantly in the shales and limestones of the Knox group and the dip is not rapid until near the river. The creek flows through a great tunnel in magnesian limestone. The limestone is so magnesian that the inhabitants of the neighborhood use it as a purgative instead of epsom salts. Midway in the cliff, which overhangs the mouth of the tunnel, is the entrance to a great cave which reaches to within 65 feet of the summit of the hill. The tunnel is 500 feet long, 25 feet high and 35 feet wide. The surveyed line of the Bristol Narrow Guage Railroad passes through it.

The elevated area known as Rye cove is but a little way east from Stock creek. There the dip of the limestones is gentle and the projecting rocks

interfere materially with agricultural operations. Between the mouth of Stony creek and Gray's ford, four miles further up Clinch river, the rocks show that they have described a fold. Along Stony creek, the calcareous sandstones at the base of the Knox group are shown succeeded by shales as near the North Fork of Clinch ; above these are massive magnesian limestones containing much oxide of iron and covered with a red soil. But, as in so many other localities, the limestones are so poorly exposed that the structure cannot be made out. Near the river, the shales are shown again and are vertical, giving evidence of having been subjected to enormous pressure.

Copper ridge lies between Clinch river and Copper creek. It consists of three narrow ridges formed by the branches of streams, which flow longitudinally through it. The low divides occasionally render this subdivision obscure, but such obscurity is usually of short continuance. The rocks belong to the Knox and the Trenton and Nashville groups of Safford. The subdivision into ridges is mainly due to the thick cherty beds of the Knox group.

A pyritous calcareous sandstone, holding some limestones, is shown at the foot of the ridge along Clinch river. It bears close resemblance to the calcareous sandstone at the base of the Knox group, so close, indeed, that the writer at one time believed that it was the same and that its presence is due to a fault. But it is not succeeded by shales such as are shown near the Hunter Valley fault.

The dip is abrupt near Clinch river, but becomes gentler within the ridge, only to become abrupt once more toward the southerly side of the ridge.

The cherty rocks of the Knox group carry brown hematites and oxide of manganese, of which fragments occur plentifully along the crests of the minor ridges. Openings have been made at several places to supply ore to White's forge on Moccasin creek; but these have been abandoned for a long time and only fragments of the ore could be found. The manganese at some localities is decidedly good, as appears from Mr. McCreath's analysis of samples from the Salling property, which is as follows :

Metallic manganese	51.495
Metallic iron	0.567
Sulphur	0.000
Phosphorus	0.027
Insoluble residue	3.030

This ore contains 10,141 per cent. of baryta. The percentage of binoxide of manganese is 81.455.

V. Area Drained by the Holston River.

No examinations were made in this area west from the Estillville and Reedy creek road.

The rocks of Moccasin ridge belong wholly to the Knox and the Trenton and Nashville groups, but the higher beds of the latter group are reached only on the northerly side of Clinch mountain. Very good exposures of

that group and of the upper part of the Knox group can be obtained in passing from Clinch mountain through Estillville and thence towards Copper creek, by either the Rye Cove or the Stony Creek road. The higher beds of the following section were seen on the former road, while the lower beds were examined on the latter. There may be an error in No. 15, for that is the horizon at which the two sections were joined, and the thickness of that mass may be greater than is given. All thicknesses are based on estimates, the dip being such that instrumental measurement is necessary for accurate determinations:

Trenton and Nashville Group.

1.	Shale and thin limestone	600′
2.	Limestone and calcareous shale	25′
3.	Calcareous shale	130′
4.	Limestone	70′
5.	Shale	65′
6.	Limestone	45′
7.	Shale	50′
8.	Massive limestones	200′

Knox Group.

9.	Cherty rock and limestone	160′
10.	Limestone and shale	120′
11.	Concealed	60′
12.	Cherty rock	165′
13.	Light blue limestone	55′
14.	Concealed	15′
15.	Limestone, shale and chert beds	300′
16.	Variegated shale	70′
17.	Limestone	250′
18.	Shale	60′
19.	Limestone	260′
20.	Shale	30′
21.	Silicious limestone	200′

Total, Trenton and Nashville, 1185′; Knox group exposed, 1745′

No. 21 is exposed along Copper creek, and is the rock which, in this memoir, has been regarded as marking the base of the upper division of the Knox group. The dip throughout Moccasin ridge is not far from 30 degrees, but the rate increases on Clinch mountain, that at the base of No. 3 being 42 degrees.

No continuous exposure of the shales, No. 1, was seen; but, as far as observed here, the features are the same as on the northerly side of Wallen's ridge. Thin limestones were seen, several of which are fossiliferous. No. 2 is well shown on the side of Clinch mountain at the residence of Mr. R. A. Ayres, opposite the village of Estillville, where it consists of limestone, 2′; calcareous shale, 10′; ferruginous shale, 5′; limestone, 8′. The upper limestone is impure, irregularly bedded, and contains a few

fossils; the lower limestone is light gray, weathers blue, is richly fossiliferous, and contains some pyrites. No. 3 is shown at the same locality, and also along the road from Estillville to Moccasin gap. It consists of red and brown shales on Mr. Ayres' property, more or less calcareous, with some beds of limestone, which become more important at the exposures near Moccasin creek. No. 4, as exposed along the road to Mr. Ayres' house, is an almost continuous mass of limestone, much of it in thick beds, and some parts of it fossiliferous. Several of the thicker layers are streaked with white calcspar. The color varies from flesh-color to light gray, and there are parts which should take a high polish and be valuable as marble. But the greater part of the mass is somewhat argillaceous, and the weathered surface shows many flaws and distinct lamination. The unequal composition of some of the thick beds unfits them for ornamental use, and their unequal resistance to the weather unfits them for building purposes. This series is well shown along the foot of Clinch mountain for many miles.

No. 5 and 6 are much alike, the great difference being in the relative quantity of limestone and shale, limestone predominating in the lower and shale in the upper bed. The limestone is more or less nodular in both. This mass reaches to the "bottom" of Little Moccasin creek and is well exposed on Mr. Ayres' property. No. 7 is conccaled in the immediate vicinity of Estillville, but a roadside exposure shows it to be filled with yellow shale.

No. 8 is an important mass, economically as well as stratigraphically. It includes the marbles of the series. The beds are all massive, from 10 to 20 feet thick, and are separated by thinner beds of shale. Many of them are finely granular, others have a conchoidal fracture; the colors are light gray, dark gray, reddish or flesh-colored, brown and nearly black. Some of the beds are streaked with white calcspar, others are fossiliferous, with the fossils replaced by calcspar, so that the rock is beautifully mottled. This effect is most striking in the reddish marbles, some of which are in no wise inferior to the Tennessee marbles used in the National Capitol. The beds are so thick that blocks of any desired size can be obtained. These marbles are well shown in the streets of Estillville as well as along the railroad line for several miles beyond that village. They are well exposed at many points along Moccasin creek between Estillville and the Russell county line. The limestone of No. 4 becomes more massive on Moccasin creek than it is nearer Estillville, so that, near the Russell county line, it might be mistaken for the marble. This series is shown in Copper ridge near Copper creek and in Big ridge, beyond Clinch river near Speer's ferry.

No. 9 is cherty. The bed immediately underlying the marbles is 12 feet thick and contains very little limestone. The rock directly under it is purer and has streaks of calcspar with lumps of chert; but the chert gradually increases downward until, at little more than midway, it predominates. With it are some beds of reddish sandstone. Toward the base, the limestone increases. This mass is well exposed on the Rye Cove road at barely half a mile from Estillville and its base is reached at a few yards above the

mill. It is the first ore horizon of the Knox group. The extensive deposit of brown hematite on Col. Shoemaker's property near Estillville evidently belongs here, as does also the fine deposit on the Big Branch of Moccasin creek at about 8 miles from Estillville. The quality of this ore is good, as appears from Mr. McCreath's analysis of samples from Col. Shoemaker's property, which is as follows:

Metallic iron	58.233
Sulphur	0.053
Phosphorus	0.075
Insoluble residue	3.840

Ore occurs at this same horizon on Copper ridge, having been opened on the McClennan property, near the Nickelsville road.

No. 10 is not fully exposed on the Rye Cove road and is better shown on the Stony Creek road. The limestone beds are from 5 to 15 feet thick and are separated by beds of shale from 10 to 20 feet thick. Very little chert was seen here. The interval, No. 11, is almost wholly concealed on the Rye Cove road and is but imperfectly exposed at other localities. On the former road, it is covered with red soil holding much jaspery rock and an excavation near its base has uncovered a thin silicious bed. At some imperfect exposures, seen elsewhere, it contains much white cherty rock. In all probability it is but a continuation of No. 12, which is very silicious and cherty in its upper part; but the limestone increases below, where chert is present only in irregular masses, which bear much resemblance to colonies of *Stromatopora*. Everywhere it shows more or less of oxide of iron and some of its cherty beds are honeycombed. Small pockets of black shale were seen in several places. This is the second ore horizon and many tons of brown hematite have been taken from it on Mr. Morrison's property near Estillville.

No. 15 is not shown in detail at any locality, but it is one of the most important members of the group, having been distinctly recognized at many localities along the summit of Moccasin ridge and along the middle and northern lines of summits in Copper ridge. For 50 or 60 feet, it is a silicious limestone, more or less ferruginous and cherty, which passes downward into a cherty rock resembling those already described and containing numerous thin beds of light gray sandstone. Below the middle a light blue limestone occurs, which weathers dirty white, and is persistent, having been observed at many places on both Moccasin and Copper ridges. Toward the base the mass becomes more and more calcareous until it passes finally into a coarsely granular massive limestone. The cherty beds are the horizon at which some of the most important ore deposits occur, brown hematite having been obtained at Mr. Poston's, in Moccasin ridge near Estillville, as well as at several other localities along that ridge; while on Copper ridge, extensive digging has been done at four places and fine blossoms were seen at many others. Oxide of manganese occurs here at one locality on Moccasin ridge and at two on Copper ridge. The manganese underlies the iron.

The limestones of No. 17 are well shown only on the northerly side of Moccasin ridge along the Stony creek road as it descends to Copper creek. They vary from flaggy to massive, from silicious to very pure, and for the most part are gray. Balls of chert were seen in some of the beds. Nos. 19, 20 and 21, are practically one. The upper part is massive and a fairly good limestone; it contains some fossils but they are indistinct. Further down, the rock becomes flaggy or thinner bedded and the silica increases, until the whole is little more than calcareous sandstone. Pyrites begins near the bottom of No. 19 and increases to the bottom of No. 21. This rock bears remarkably close resemblance to that which lies at the base of the Knox group along the line of the Hunter Valley fault.

Clinch mountain is a bold rugged ridge, very narrow, and showing a sharply serrate crest. For nearly 50 miles it has but one water gap, and its slopes are so steep that no wagon road passes over it within Scott county, while trails for riding animals are few and difficult.

The Medina sandstone is reached at the summit of the mountain, and for a long distance forms the southerly slope, the newer rocks being found only near its foot. It is exposed imperfectly in Moccasin gap, but its composition is shown there better than at any other locality within Scott county. The succession as there observed is as follows:

1.	Massive sandstone, much of it conglomerate, dark gray to almost milk white	75′
2.	Massive sandstone, almost like quartzite, no grains shown on weathered specimens; weathered surface is rough and jagged; color on fresh surface, bluish white	150′
3.	Concealed, but evidently containing some shale as well as some white sandstone	30′
4.	Like No. 2 except that in some portions the surface of weathered specimens glistens, while the other always shows a dead white surface; weathered surface irregular	60′
	Total	315′

In many respects, this rock bears much resemblance to the silicious beds of the Knox group; so much, indeed, that one would find difficulty sometimes in deciding the relations of a hand specimen.

Immediately above No. 1 of the section, there is in the gap a hard flinty rock belonging, in all probability, to the Lower Helderberg. It is irregularly bedded, loaded with oxide of iron, contains no fossils, and is not more than 15 or 20 feet thick. Above this come the Hamilton shales. The Clinton group and the Oriskany sandstone are evidently absent.

The Medina carries a brown hematite which has been examined at 3, 6, and 14 miles east from Moccasin gap. Samples taken from Mr. Ayres' property at 3 miles above the gap were analyzed by Mr. McCreath, with the following results:

Metallic iron	43.825
Sulphur	0.029
Phosphorus	0.926
Insoluble residue	19.910

Ore from another locality was mined for White's forge on Moccasin creek, and it is said by Mr. White to have proved even better than the ores from Moccasin ridge.

The Lower Helderberg is fairly well shown at little more than 2 miles east from Moccasin gap, where a fine grained sandstone, almost a true grit, rests on the Medina conglomorate. It contains many fossils, mostly indistinct, among which are *Spirifer* and *Platyceras*, nearly allied to Lower Helderberg forms. This rock shows no traces of iron ore, but immediately above it is a fossiliferous brown hematite, which has evidently replaced a limestone bed. The ore is bulky, and consists chiefly of casts of a *Favosites*, which is somewhat coarser than *Favosites helderbergiæ*, and resembles more a form occurring in the Coniferous. A cyathophylloid coral was obtained from the ore, but it has been misplaced. No other exposure was found.

The Hamilton shales are exposed at the mouth of Moccasin gap and thence to a considerable distance up the side of Brushy mountain. Above these are the Chemung sandstones, containing *Spirophyton* and *Spirifera disjuncta*, and forming the crest of Brushy ridge, the first ridge of Brushy mountain. The second ridge of that mountain is made up of Lower Carboniferous rocks, which continue along the Reedy creek road, to say a mile beyond the North Fork of Holston river. They describe a synclinal at the river. The abutments of the river bridge were constructed of rock from one of the higher limestones, which is composed almost wholly of *Fenestella*. The highest beds of the Lower Carboniferous are mostly bluish grits, with some impure limestones, and are well exposed along the road as it follows a little ravine beyond the Holston river.

The fault of North Fork of Holston is reached along this road at about a mile from the river or near the head of the narrow gap just referred to. This uplift brings the limestones and cherts of the Knox group again to the surface and these continue as the surface rocks to the Tennessee line. Their features are the same as on Moccasin ridge.

A "poor valley" between Clinch mountain and the first ridge of Brushy mountain, extends from the Tennessee line to far beyond the limits of this reconnaissance in Washington county. The Hamilton shales are exposed at many localities in it, but the succession of the group is obtained best by tying the partial section made in Moccasin gap to that made along the railroad grade between Mendota and the North Fork of Holston. The estimated thicknesses are as follows:

1. Dark sandy shale, fossiliferous, shown in the railroad excavations ..... 130′
2. Yellow to ash colored shales, mostly well exposed in the railroad excavations, but the base seen only on the Abingdon road between Mendota and Moccasin gap; dip 45 to 50 degrees ..... 550′

3. Dark fissile shale, with thin beds of sandstone, partial exposures between Mendota and Moccasin gap, but best shown in the gap..... 150′

Total..... 830′

The sandstone beds in No. 3 are fine-grained, very white and prove to be an excellent firestone. These are shown in the Abingdon road at several localities between Mendota and Moccasin gap, as well as just below the mouth of the gap. Much of this material was used for lining at Bushong's furnace, 40 miles away in Tennessee, to which it was carried by wagon. The shales are very dark, and at many localities along the foot of Clinch mountain they are as badly wrinkled as mica schist, but they show no evidence of metamorphism. Two thin beds of highly carbonaceous shale occur at the base of this group, which have been mistaken at several places for *coal*. They contain enough carbonaceous matter to burn and sometimes they yield a piece of fairly good *coal*.

The Chemung rocks are shown in all the ravines crossing the first ridge of Brushy mountain. An excellent exposure is afforded by the railroad excavation near the North Fork of Holston river, where the group is represented by shales and sandstone, mostly brownish gray and not far from 300 feet thick. A conglomerate layer, 4 to 6 inches thick, was seen very near the top and another of about the same thickness at 20 feet lower. Fossils were found immediately above the upper layer as well as at 10 feet below it; among these are *Spirifera disjuncta*, *Atrypa aspera* and a *Chonetes*. For the most part the specimens are badly preserved, as the layers in which they occur are ferruginous grits and the fossils are recognizable only on the weathered surface. *Spirifera disjuncta* and *Productella boydii* were found on fragments of sandstone belonging midway in the group, and a *Spirophyton* covers many layers near the base.

The Chemung is succeeded by the lower member of the silicious group of the Lower Carboniferous. The two groups are conformable, and the junction is well shown in the railroad cut.

A good section of the Lower Carboniferous was obtained between this point and the Holston fault by following the railroad line. It is as follows:

Mountain Limestone Group.

1. Sandstones, limestones and shales..... 800′
2. Calcareous shales..... 60′
3. Concealed..... 40′
4. Calcareous shale..... 100′
5. Limestone..... 105′
6. Imperfectly exposed..... 250′
7. Limestone..... 15′
8. Shales..... 20′
9. Limestone..... 50′
10. Shale, imperfectly exposed..... 65′
11. Limestone..... 15′

12.	Shale	80′
13.	Limestone	5′
14.	Shale	75′
15.	Limestone	20′
16.	Shale	150′
17.	Limestone	5′
18.	Shale	60′
19.	Limestone	80′
20.	Argillaceous limestone	60′
21	Granular to argillaceous limestone	100′
22.	Argillaceous limestone	35′
23.	Concealed	25′
24.	Granular limestone	30′
25.	Granular limestone	25′
	Silicious Group.	
26.	Cherty limestone	70′
27.	Granular limestone	35′
28.	Cherty massive limestone	65′
29.	Concealed	10′
30.	Limestone	30′
31.	Concealed	50′
32.	Limestone and shale	40′
33.	Massive limestone	125′
34.	Shales and thin limestones	90′
35.	Limestone	80′
36.	Calcareous shale	35′
37.	Limestone	25′
38.	Shales, sandstones and calcareous grits	100′

Total, Mountain Limestone group, 2270′ ; Silicious group, 755′

These thicknesses are all estimated, except those from No. 7 to No. 15. No. 1 was seen in the gorge of Wolf creek ; Nos. 2 to 20 inclusive were obtained along Abraham creek ; Nos. 21 to 30 inclusive are exposed in the river bluff below the railroad bridge ; and Nos. 31 to 38 are shown in the railroad excavations along the river bank.

No. 1 shows much the same features as in Pennington's gap, as well as along the road leading south-east from Moccasin gap. Its base is reached at the forks of Abraham's creek, at say one mile from the North Fork of Holston river. This mass forms the left hand wall of Wolf Creek gorge, through which the railroad passes for several miles. Here, doubtless, a detailed section could be obtained, but the wall is very steep and its ascent would be attended with danger. The greater part of the rock is a more or less ferruginous calcareous grit, much of which is dark blue on the fresh surface ; but the iron and lime are easily leached out, so that, on exposure, fragments become "rotten" to a depth of several inches. Some portions are very fine-grained and hard, so as to be fit for grindstones ; these are

well shown on a fork of Wolf creek, known as Whetstone hollow. A few of the beds are fossiliferous, but nothing can be obtained from a fresh piece, while the weathered specimens are so tender that specimens are ruined in the effort to free them from the rock. Huge stems of crinoids and some indistinct specimens of *Chonetes* were seen. The limestones are light blue, argillaceous and non-fossiliferous. The shales are usually reddish, but they form only a small part of the mass. No massive sandstone was observed here such as was seen in Pennington's and Big Stone gaps.

Nos. 2, 3 and 4 probably should be accounted as part of No. 1, but the shales, for the most part, are calcareous and resemble some lower beds more than they do those of Wolf creek. The shales, Nos. 8, 10, 12, 14, 16 and 18 are light blue to reddish blue on the fresh surface and weather to a dirty or muddy yellow. A fresh edge seldom shows lamination, but the weathered surface shows it distinctly. These beds are generally well exposed in the bed of Abraham's creek, along side of which the railroad grade runs. Fossils occur rarely in these shales, and the only distinguishable specimens seen belonged to a broad form of *Spirifera leidyi*.

The limestone, No. 5, well exposed at the roadside and in the hills at but a little way below the mouth of Wolf creek, is blue, but weathers yellowish white; it is composed chiefly of a *Fenestella*, but some layers have many specimens of *Athyris* and *Productus*. Nos. 7 and 15, both of which are well shown in the creek bed as well as in the hill, have a similar origin, and the *Fenestella* is distinctly shown throughout with only a rare *Productus* and *Zaphrentis*. These two beds are exceedingly hard. No. 15 is the same with that of which the bridge abutments for the Reedy Creek road were constructed at the North Fork of Holston river.

No. 6 continues from Mr. Kaylor's residence on Abraham's creek down the stream almost to his mill, at probably two-thirds of a mile from the river. It has more than one bed of limestone and is closed by a sandstone at the top. Below this interval, the section is almost continuous to the base of the series. No. 9 is shown at the mill; it varies from light to dark blue or almost black, and shows many stems of crinoids, with *Fenestella* and a *Spiriferina* closely allied to *S. kentuckensis*. No. 11 is a handsome light blue limestone and contains *Athyris subquadrata*, *Productus cora* and crinoid stems, which occur also in Nos. 17 and 19. No. 21 is an important bed, which is shown at the mouth of Abraham's creek and forms a broad band on the cliff around the bend of the river below the railroad bridge. For the most part, it is coarsely granular and dark gray, but it contains some argillaceous layers and becomes a blue grit near the base. It yields an admirable building stone, of which the bridge abutments and pier have been constructed. The rock is very pure and burns into a beautifully white lime, which shows no trace of iron when slaked.

No. 22 is argillaceous and its fragments cover the narrow bank below the bridge. This is by far the most fossiliferous bed of the whole series; *Productus cora*, *Productus elegans*, *Athyris subquadrata*, *Spirifera leidyi*, *Hemipronites crassus*, *Pinna* and *Allorisma* having been obtained from a

small block. Perhaps this should include also the concealed interval below it.

Nos. 24 and 25 are very similar to No. 21; they are granular, and No. 24 is massive. No. 25 is more or less flaggy, and passes into a hard, cross-bedded calcareous grit, which contains not a little chert.

The limits of the two groups are very distinct, and only a few feet at the bottom of No. 25 mark the transition. Below that line, chert is present in nearly every bed. Nos. 26, 27 and 28 are alike, except that very little chert occurs in No. 27. Many layers of No. 26 are crowded with bryozoans, and the smaller nodules of chert are casts of *Productus*. Crinoid stems are abundant in No. 28, which is massive and cherty throughout. No. 33 is well exposed in the railroad excavation; its higher beds are dark gray, streaked with white calcspar and contain much chert, some of which certainly has replaced a *Chætetes*-like form. Fossils occur in the highest beds, where sections of *Productus*, *Athyris* and *Pleurotomaria?* are abundant; the lower beds are massive, almost black, and show only minute fossils. No. 35 is very cherty in its upper and massive layers, but the lower layers are somewhat flaggy, show little chert, and are crowded with crushed fossils, chiefly *Hemipronites* and *Athyris*. No. 37 is flesh colored to light blue, and is well exposed at the mouth of a hollow nearly half a mile from the bridge over North Fork of Holston. There it describes a short abrupt anticlinal, which is nicely shown in the railroad side-cutting. This bed is the base of the upper member of the Silicious group.

No. 38 is the Protean member of the Silicious group. It is not fully exposed as the little hollow, already referred to, intervenes between the last exposure of the limestone and the first exposure of this mass, the concealed interval being perhaps 35 or 40 feet. But under the petty anticlinal, the upper part of No. 38 is shown within 5 feet of the limestone, the interval being filled with some drab clay, which may belong with either No. 37 or No. 38. The upper part of No. 38, as far as seen, is a fine-grained sandstone with smooth fracture, but this passes downward into shales containing a bed which is highly carbonaceous. The rocks below are fine-grained sandy shales with beds of blue calcareous sandstone or grit, very fine-grained and breaking with irregular fracture. These are very similar to the beds seen in No. 1 of the section. It is possible that *coal* occurs in the concealed part of this mass, for a *coal bed* is said to be present under the river directly opposite the mouth of the little hollow. The only fossil seen in these rocks was a fragment, which probably belongs to *Leiorhynchus*.

These beds rest comformably on the Chemung, as already stated.

The dip of the rocks varies. In No. 35 it is nearly 20 degrees; in No. 25 it is 33 degrees and the strike is N. 60° E. mag.; but here the rate increases, and in No. 24 it becomes 40 degrees, which is the prevailing rate of dip up to within 300 yards of the mouth of Wolf creek, beyond which no measurements were made. It is not at all improbable that a fragment of the Quinnimont group remains on the high land between Abraham's creek and Wolf creek.

The Holston uplift is reached at the summit between Wolf creek, North Branch, and the "rich valley" of Abraham's creek. There, one comes to the limestones of the Knox group, in contact with the highest rocks of the mountain limestone group, and two miles further along the railroad line the cherty beds of the Knox group are exposed. These are shown very near to Walker's mountain at a cross-road, where the soil is very ferruginous. The limestones of the overlying group are shown at but a little way from the gap by which the railroad passes through Walker's mountain.

A well-marked fault was crossed just behind Walker's mountain at somewhat more than four miles from Bristol, where the pyritous calcareous sandstones of the Knox group are shown in the gap through that ridge. The dip is abrupt at the head of the gap and increases to the mouth, where it becomes nearly 50 degrees, and the shaly layers are badly twisted. Exposures are very obscure between this locality and Bristol, where the line of section terminated; but the limestones of the Knox group are shown here and there, and the cherty beds of that group pass very near to Bristol.

Photodynamic Notes. By Pliny Earle Chase, LL.D.

(*Read before the American Philosophical Society, January* 21, 1881.)

1. *Chemical Synchronism.*

Maxwell* appears to have originated the theory, which is now generally accepted, of the equality of mean *vis viva* in the molecular movements of different gases, at equal temperatures. In 1863, I began to investigate some of the consequences of the theory, and the many evidences which I have adduced, of cyclical and harmonic vibrations in atmospheric and æthereal media,† have more than justified my belief of its importance.

All harmonies in elastic media necessarily involve some form of synchronism, and the progress of chemical physics may be helped by a knowledge of the general kinetic laws upon which such synchronism depends. If we designate velocity by v; density, by d; time of rotation, by t; modulus, by h; absolute temperature, by T; and the acceleration of a central force, by f, Maxwell's theory may be represented by the equation $v^2 d = k T$. In the fundamental equations of central force $v = \frac{f t}{2} = \mathrm{F}\sqrt{fr}$; $h = \frac{ft^2}{4}$. When the efficient or fundamental velocity is constant, as in spatial Photodynamics, $f \propto \frac{1}{t} \propto \frac{1}{h} \propto \frac{h}{t^2} \propto \frac{1}{r}$; $t \propto h \propto \sqrt{\frac{h}{f}} \propto r \propto \frac{1}{f}$; $h \propto r \propto \frac{1}{f} \propto ft^2 \propto t$. Whenever we have occasion to consider derivative or second

* P. Mag., 1860 [4], 19, 19.

† Proc. Amer. Phil. Soc., ix, 284-7; xvii, 109-12, 294-307; xviii, 224-32; xix, 4-9 20-5; *et al.*